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Additional Information (when applicable)

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1. FGM 160 – USER MANUAL - TABLE OF CONTENTS

2. INTRODUCTION

2.1 Introduction

- Fluenta is the world leader in ultrasonic flare metering, headquartered in Bergen, Norway. Fluenta have more than 850 ultrasonic flare metering systems in operation worldwide. Fluenta have offices in Paris, Dubai and Houston.

- The Fluenta Flare Gas Meter is the most robust and accurate flare meter on the market today able to cover higher velocity ranges than any other flare meter. It is an essential monitoring tool for E&P operators.

1.It all began in 1982

1982 – 1986.
The Fluenta Flaregas meter was developed by Christian Michelsen Institute

1985.
Christian Michelsen Institute founded Fluenta AS

1987.
First Fluenta Flaregas meter in operation

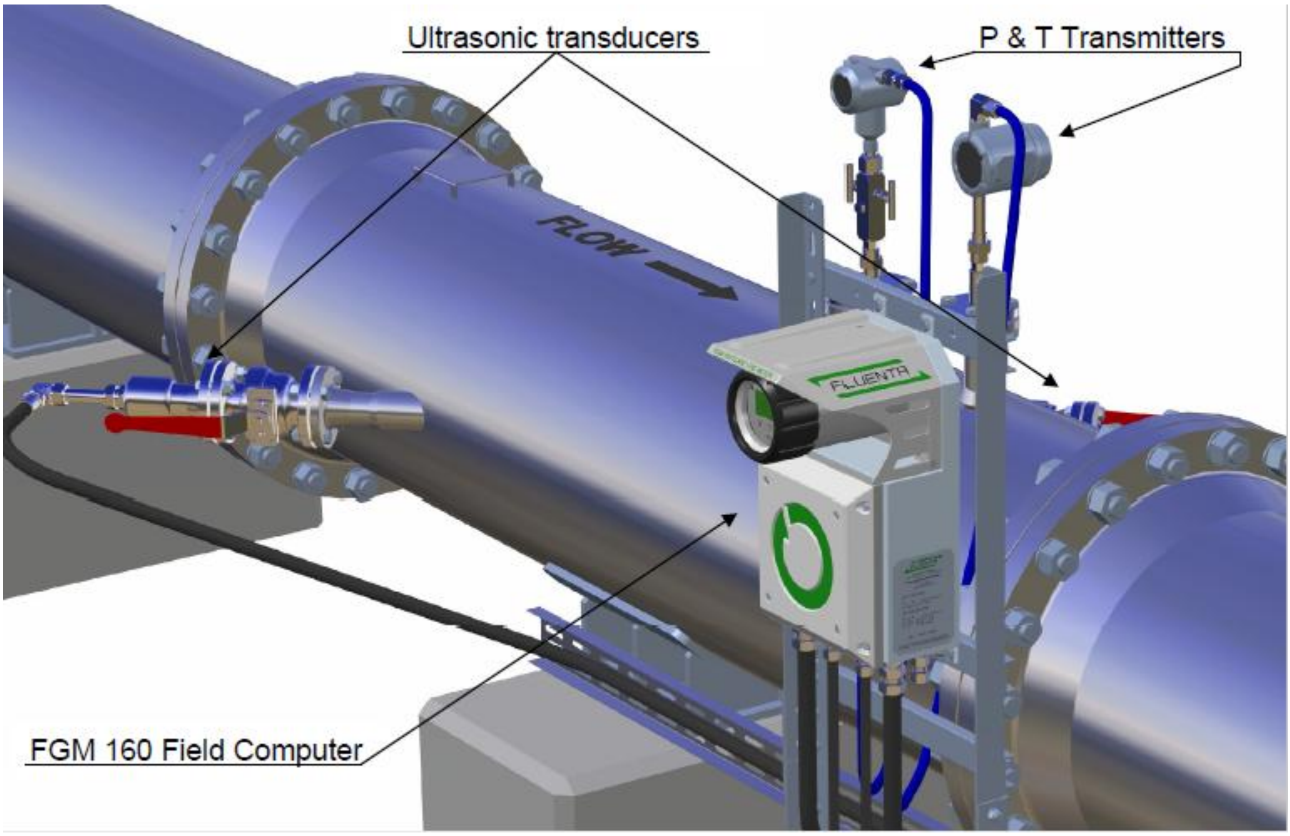
2001.
Roxar acquires Fluenta AS.

2007.
Roxar s management board makes a strategic decision to divest its flaring business.

9th May 2007.
The new owners of the flaring business establish the new Fluenta AS.
Personnel with a total of almost 100 years of experience with ultrasonic flare measurement follow the flare business from Roxar to Fluenta.

2009.
Fluenta is a worldwide organisation with offices in Paris, Dubai, Houston and Bergen.

2.The Fluenta FGM 160



- The FGM 160 is an Ultrasonic meter based on Time-of-Flight transit time measurement. It is non-intrusive for all pipe diameters, and has a measurement uncertainty of ±2.5-5% over the standard flow velocity range of 0.03-100m/s. An extended flow range of up to 120m/s and improved uncertainty is feasible depending on process parameters. Contact Fluenta Sales Dept. for more information.

- The FGM 160 flow computer is field mounted, and can be fully operated from any location when connected up via Modbus to the unique software operator panel.

3. Fluenta Quality Assurance

Quality Management System (QMS)
The QMS covers the design and production of the company´s products and services.

Health, Safety & Environment Management System (HS&E)
The purpose of Fluenta's HS&E Management System Manual is to describe the overall HS&E standards and goals in Fluenta.

ISO 9001:2008 Certified
Fluenta AS has implemented and maintains a Quality Management System which fulfills Nemko's provisions for Management System Certification and the requirements of the following standard NS-EN ISO 9001:2008.


IQNet
THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and Nemko AS
hereby certify that the organization

Fluenta AS
Nesttun, Norway

for the following field of activities
Development, manufacturing, sales, installation, customer services and support of metering/monitoring systems and equipment for flow control for the petroleum- and other industries; including products for use in hazardous areas.

has implemented and maintains a
Quality Safety Management System

which fulfils the requirements of the following standard

ISO 9001:2008

Issued on: 09.06.2009
Validity date: 15.07.2011

Registration Number : NO-900998

René Wasmer
President of IQNet

Pål Eddie
Nemko AS
Certification Dept.

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3. MAIN DATA

3.1 Utility Consumption Data
3.2 FGM 160 Data Sheet
3.3 Weight Data Sheet

3.1 Utility Consumption Data

1. Purpose

This document gives the utility consumption requirements for the Fluenta Flare Gas Meter, FGM 160.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM - Flare Gas Meter

2.2 Definitions:

N/A.

3. Utility Consumption Data

The FGM 160 utilizes 24 VDC supply voltage.

4. Nominal Power Consumption

Under normal circumstances the FGM 160 will consumption approximately 250 mA with a supply voltage at 24 VDC. Accordingly, the nominal power consumption will be approximately 6 VA or 6 W.

5. Maximum Power Consumption

In a scenario where all ports within the system are being used and the system is fully loaded, maximum power consumption will not exceed 13 VA or 13 W.

6. References

N/A.

3.2 FGM 160 Data Sheet

1. Purpose

This document specifies the general, environmental, electrical and operational data of the Fluenta Flare Gas Meter, FGM 160.

2. Abbreviations/Definitions

2.1 Abbreviations:

TFS Transducer Full Size

2.2 Definitions:

EEx-d/e FGM160 Field Computer Electronics Unit in EEx-d explosion proof enclosure and connection housing in EEx-e enclosure.

3. General

3.1	Sensor Type	Ultrasonic / Time-of-Flight - Full Size and Compact Version (Wetted parts, but not intrusive)
3.2	Sensor Material	Titanium/SS316 or Titanium/6Mo
3.3	Certification	ATEX: Nemko 07ATEX1160 CSA: CSA 2241432 GOST-R: 8468425 GOST-K: KZ7500361.01.01.16570
	Field Computer	Ex de [ia] IIC T6, Tamb: -40 °C to + 60 °C
	Ultrasonic Sensors	Ex ia IIC, T6: Tamb: -70 °C to + 60 °C T5: Tamb: -70 °C to + 85 °C T4: Tamb: -70 °C to + 120 °C
3.4	Service	Flare Gas Measurement and other low pressure hydrocarbon gas flow measurements

4. Operating Limits

4.1	Pipe Sizes	6" – 72" (other pipe sizes on request)
4.2	Temperature	
	Field Computer	-40 to +60 °C (-40 to +140 °F)
	Ultrasonic Sensor	-70 to +145 °C (-94 to +293 °F) *)
4.3	Pressure Rating	ANSI CLASS B16.5 150# RF, 0.8 – 10 barA

*): Lower temperatures than -70 °C for short period of times.

5. Design Limits

5.1	Design Temperature	-150 to +315 °C (-238 to +599 °F) (transducers) *)
5.2	Design Pressure	20 barA (transducers) *)

*): Mechanical survival ratings, NOT operational survival ratings.

6. Electrical Data

6.1	Supply Voltage	24 VDC (20 - 32 VDC) (230/110 VAC 50/60 Hz optional)	
6.2	Power Consumption	13 VA max	
6.3	Input Signal	Transit times;	from ultrasonic transducers
		Temperature;	analogue 4-20 mA, or digital HART communication
		Pressure;	analogue 4-20 mA, or digital HART communication
6.4	Analogue Output Signal	3 x analogue 4 - 20 mA outputs (Additonal 3 x analogue 4-20 mA or 1 x HART outputs optional)	
		Each output channel can individually be set to one of the following: • Volume flowrate at reference conditions • Volume flowrate at line conditions • Mass flow • Density at standard conditions • Density at operational conditions • Molecular weight • Alarm High • Alarm Low • Temperature • Pressure	
6.5	Pulse/frequency Output	1 x Pulse/Frequency outputs. f_{max} = 4 kHz	
6.6	Serial Link to DCS	RS422 / RS485, 2- or 4-wire	
		Modbus protocol, ASCII or RTU	
6.7	Serial link to O&SC *)	RS485, 2- or 4-wire	
		Modbus protocol, RTU	

*): Operator & Service Console

7. Functional Characteristics

7.1	Flow Velocity Range	0.03 - 100 m/s (0.1 - 328 ft/s)*
7.2	Uncertainty at 95 % confidence level with fully developed turbulent flow profile	± 2.5 % - ± 5.0 % of measured value Q_v**
7.3	Resolution	0.0008 m/s (0.03 ft/s)
7.4	Repeatability	Better than 1% of volume flow for velocity 0.3 - 100 m/s (1 - 328 ft/s)
7.5	Turn Down Ratio	3330:1
7.6	Calibration	Zero flow calibration

* Above velocity specification is in accordance with Fluenta's standard range. Extended performance up to 120m/s is feasible depending on process parameters.
** Wet (flow) calibration on a third-party rig for improved measurement uncertainty is possible to offer.

8. Measuring Section

8.1	Material Wetted Parts	Stainless steel 316L (Nace MR 0-175) or to customer's specification
8.2	Ball Valves	2" 150# RF Full bore to customers' specification
8.3	Upstream Straight Pipe Requirements	10 x ID (20 x ID: Norwegian Petroleum Directorate regulation)
8.4	Downstream Straight Pipe Requirements	5 x ID (8 x ID: Norwegian Petroleum Directorate regulation)
8.5	Dimensions	Transducer length: Transducer Full Size - TFS; In operation 0.71 m (2.33 ft). Retracted: 1.03 m (3.38 ft)
8.6	Installation	45° angle: centre line transducers / run pipe
		Transducers: 6"- 10" → pipe; 42° / 48°
		12"- 72" → pipe; 45° / 45°
		Special metering / welding jigs to be used during installation of transducer holders

9. Field Computer

9.1	Installation	Ex-d/e enclosure
9.2	Local Display	Parameter viewing of predefined set of process parameters *)
9.3	Dimensions	280 x 470 x 290 mm (W x H x D)
9.4	Weight	App. 17 kg

*): Predefined parameter set;

- Volume flowrate @ actual (flow) conditions
- Mass flowrate @ actual (flow) conditions
- Totalized volume flow
- Totalized mass flow
- Last 24h totalized mass flow
- Pressure
- Temperature

10. Operator Console

10.1	System View	Single System View; detailed data view, trend log, configuration
10.2	SW upload	Via integrated Service Console
10.3	Remote Operation	Via RS485-TCP/IP interface or Remote Control Software

11. References

N/A.

3.3 Weight Data Sheet

1. Purpose

This document specifies the weight of the components included in the Fluenta Flare Gas Meter, FGM 160.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM 160 Fluenta Flare Gas Meter, model FGM 160
TFS Transducer Full Size

2.2 Definitions:

EEx-d/e FGM 160 in EEx-d explosion proof enclosure and connection housing in EEx-e enclosure.

3. Weight Data Sheet

3.1 Transducer Full Size (TFS) Weight Data Sheet

Table 1 indicates the weight of an FGM 160 with up to two sensor pairs. The sensors involved are Transducer Full Size (TFS) and the FGM 160 in an EEx-d/e housing. All weights are listed in [kg] and [lbs].

Table 1 – Transducer Full Size and EEx-d/e housing

Weight data	Unit		1 system		2 systems	
	[kg]	lbs	[kg]	[lbs]	[kg]	[lbs]
EEx – d/e enclosure	17	37.5	17	37.5	17	37.5
Transducer FGM 160	10	22	20	44	40	88
Ball valve (typical) incl. bolts and nuts	14	31	28	62	56	123
Transducer holder	5.5	12	11	24	22	48
Transducer cable	0.085 kg/m	0.056 lbs/ft				
Power cable	0.20 kg/m	0.13 lbs/ft				
Complete system			76	167.5	135	296.5
Approx. shipping weight			128	281.6	239	528.8

Note! Cables are not included in the weight of the complete system as it depends on the specific cable length, but weight per unit length is indicated.

4. References

N/A.

4. TECHNICAL DESCRIPTION

4.1 Functional Description
4.2 Flow Calculations
4.3 Cable Descriptions

4.1 Functional Description

1. Purpose

This document describes the Fluenta Flare Gas meter, FGM 160. The main components in the system are described and the measuring techniques are explained.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM	Flare Gas Meter
TFS	Transducer Full Size

2.2 Definitions:

N/A

3. General

3.1 Reference Conditions

The following reference conditions are used as a basis:

Pressure	:	1.01325 bar a
Temperature	:	15 °C = 288.15 K

3.2 Units of Measurement

The following units of measurements are used in the FGM 160:

Measurement		SI	U.S.
Length	:	mm	in
Area	:	m^2	ft^2
Volume	:	m^3 or Sm^3	cf or Scf
Mass	:	kg	lb
Volume flow rate	:	m^3/h or Sm^3/h	MMCFD or MMSCFD
Mass flow rate	:	kg/h	lb/h
Density	:	kg/m^3	lb/ft^3
Pressure (absolute)	:	bar a	psi
Temperature	:	°C	F

3.3 Language

The FGM 160 is supplied with English text as standard.

4. General Technical Descriptions

4.1 Challenges Involved in Flaregas Metering

Challenges that must be overcome in order to measure flare gas are among others:

- Large velocity variations for the gas flowing in the flare pipe.
- Large pipe diameters.
- Low pressure situation at the metering point.
- Field-mounted sensor shall operate in explosive or potentially explosive areas, thus limited power is available.

The FGM 160 is designed to operate under these difficult conditions and the capability to do so is verified by instruments presently in operation. The ultrasonic sensors are wetted but non-intrusive, and will thus not disturb the flowing gas. The meter has no mechanical moving parts, which makes the instrument less exposed to wear.

The problem associated with high flow velocities is, among others, that the gas flowing in the pipe represents a source of noise, which reduces the recognisability of the transmitted, ultrasonic signal. Also, high gas velocities will carry the ultrasonic pulses along the pipe, which makes it even more difficult for the sensors to communicate.

Low pressures, large pipe diameters and limitations on the amount of electric power that can be applied due to explosive area regulations, are all elements that increase the difficulty in obtaining good measurements. These problems are solved by using two different types of signals, Continuous Wave and Chirp. This measurement technique is described further in this document.

4.2 General Description of FGM 160

The FGM 160 system consists of a Field Computer and a transducer pair. Transducers are ultrasonic sensors mounted on the flare gas pipes, ref. Figure 1.

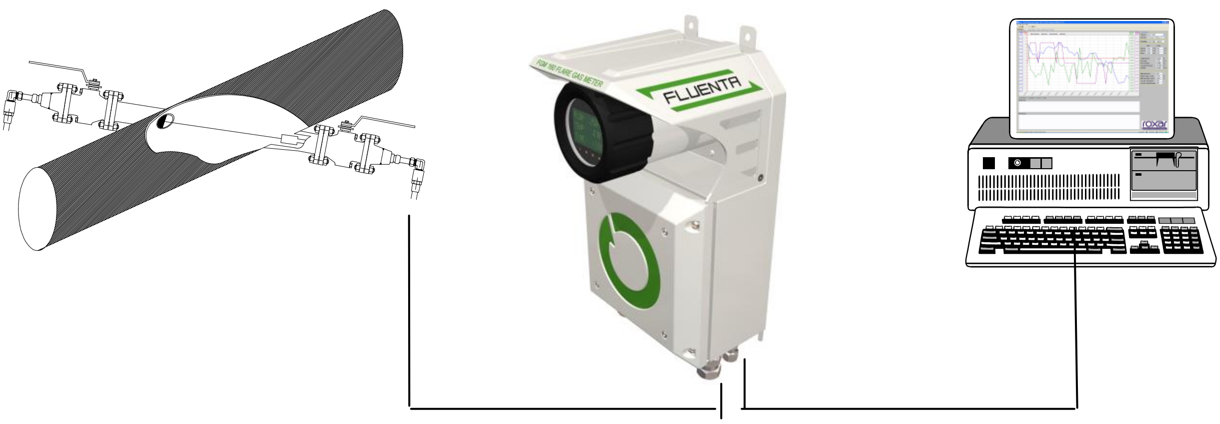


Figure 1 The FGM 160 system with one pair of ultrasonic sensors.

The FGM 160 measures the gas velocity with the by using of the time of flight technique, which means that the ultrasonic transducers communicate with each other by transmitting and receiving ultrasonic signals.

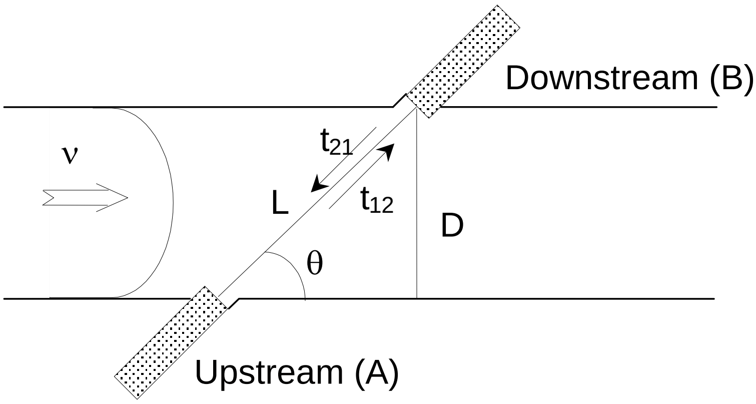


Figure 2 Transit time measurement principle.

With reference to Figure 2, the measurement principle may be explained as follows:

Both transducers transmit and receive ultrasonic pulses and the difference in transit time between the downstream pulse (from A to B) and the upstream pulse (from B to A) is measured. When gas is flowing in the pipe, a pulse travelling against the stream (upstream) will use longer time to reach the opposite transducer than a pulse travelling with the flow (downstream). This time difference is used to calculate the velocity of the flowing medium by the following equation:

$$v = \frac{L}{2\cos\theta} \cdot \frac{t_{21} - t_{12}}{t_{12} \cdot t_{21}}$$

where:

v = axial velocity of flowing medium without compensation for Reynolds Number variation

L = distance between transducer tips

θ = angle of intertransducer centre line to axis of pipe

t_{12} = transit time (sec) from Transducer (A) to Transducer (B) (downstream)

t_{21} = transit time (sec) from Transducer (B) to Transducer (A) (upstream)

4.3 Detailed Explanation of the Measurement Signals

As outlined in section 4.2, the measurement principle is based on transit time difference. This section gives a more detailed description of the signal types used to perform the measurements. Two different signal types are used, and the combination of these two makes the FGM 160 a unique instrument for flare gas measurement purposes.
The two signal types used are:

CW - Continuous Wave (Signal burst)
Chirp - Variable frequency signal

4.3.1 Continuous Wave (CW) Measurements

This CW signal has a constant frequency and amplitude as illustrated in Figure 3.

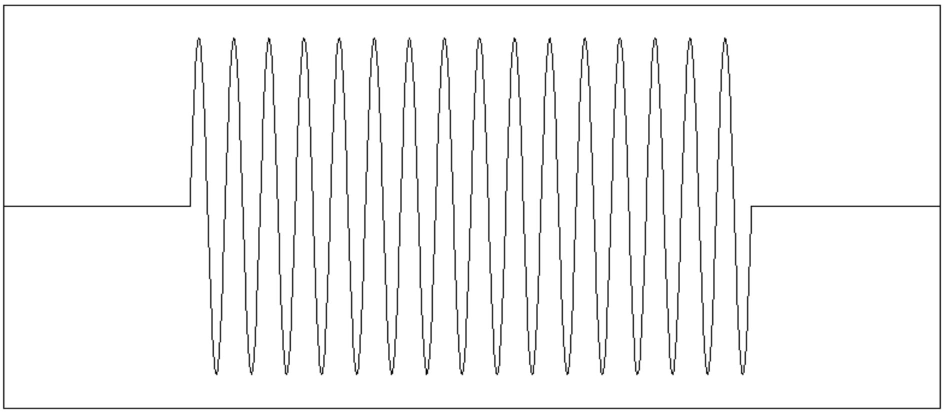


Figure 3 Continuous Wave (CW) signal (burst).

This is general signal type used in ultrasonic instruments. When measuring flare gases at high velocities, the medium in the pipe line will generate significant acoustic noise. This acoustic noise may have equal or higher amplitude than the CW signal, which makes detection difficult, if not impossible. This signal is therefore only suitable for measurements at low gas flow velocities.

4.3.2 Chirp Measurements

According to section 4.3.1, CW signals are not suitable for measuring flare gases at high velocities. A solution to this problem is to use a time varying signals instead, called Chirps. These signals are given a unique recognizable form characterised by the pulse duration and the varying signal frequency. Their unique form makes them detectable through the acoustic noise induced by the flowing medium. Figure 4 illustrates a Chirp signal with varying frequency and fixed amplitude.

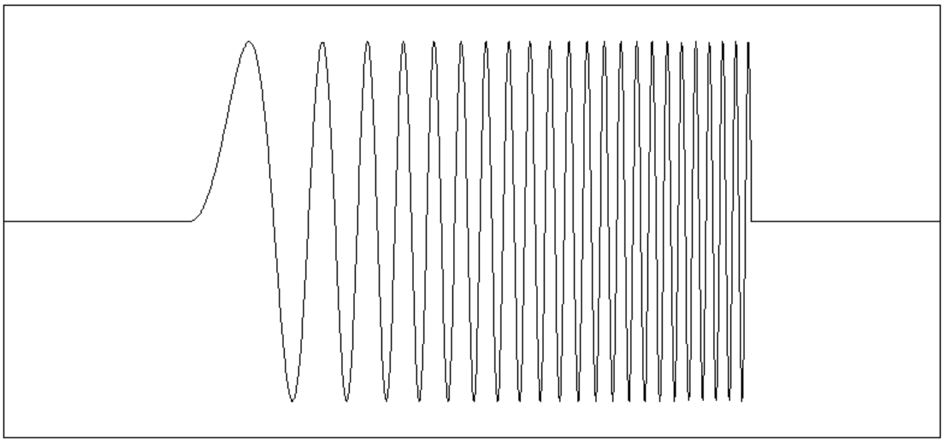


Figure 4 Chirp signal, with varying frequency and fixed amplitude.

Chirp signals are used in combination with CW signals for measuring flare gases at low velocities. At higher velocities the instrument only utilizes Chirp signals.
The combination of Chirp and CW at low velocities enhances the accuracy of the FGM 160 measurements for these velocities.

5. Field Computer Unit

5.1 General

The processing of the information from the transducers and from the pressure and temperature transmitters are performed in the FGM 160. The Field Computer controls the transmission to and detection of signals from the transducers and performs the critical transit time measurements. The Field Computer also performs calculations based on the time measurement results and presents data and alarm messages.

5.2 Field Computer Description

The FGM 160 Unit, shown in Figure 5, consists of two enclosures, the EEx-d enclosure and the EEx-e enclosure. The EEx-d enclosure contains the computer unit and all the system electronics. The computer unit and the electronics form a stack, with defined and distributed tasks. A distributed system will be more flexible with respect to future expansions and modifications, as the total processing load for the system can be divided on several modules. Thus, the danger of overloading a single CPU unit is reduced.

The PCB stack module can be divided into five main components or units. A Local Display has been standard for the FGM 160 since 2007, completing the PCB stack with a total of 6 boards.

Figure 5 FGM 160 Field Computer.

5.2.1 DSP; Digital Signal Processing

The Digital Signal Processing unit is the systems master. The DSP unit generates the measurement signals and controls the measurement sequences. It collects data from the other module registers and performs flow calculations based on this data. All calculated parameters are stored in defined registers and made available for the DCS system and the Operator & Service Console through the I/O unit.

5.2.2 AFE; Analogue Front End

The Analogue Front End unit is the interface between the DSP unit and the ultrasonic transducer sensors via the IS-Barrier unit. At the AFE unit, measurement signals are multiplexed and switched between CW- and Chirp-signals, and upstream and downstream direction.

5.2.3 P&T; Pressure & Temperature

The Pressure & Temperature unit collects pressure and temperature information from external sensors via 4-20 mA current loop or HART interface. All pressure and temperature data are stored in predefined registers available for the DSP unit. Thus, the DSP unit can retrieve P&T parameters in a minimum of time.

5.2.4 I/O; Input/Output

The Input/Output unit is the interface between the FGM 160 in hazardous area and equipment in safe area. At the I/O unit, 24 VDC supply voltage is converted to the required operational voltages for the other units in the stack. Further, all signals and communication to and from the DCS system and Operator & Service Console are handled by this unit.

5.2.5 IS-Barrier; Intrinsic Safety Barrier Module

The Intrinsic Safety Barrier Module ensures the intrinsic safety to the ultrasonic sensors mounted in hazardous areas. The total energy is kept within safe limits to prevent explosions due to excessive heat. In addition, the IS-Barrier unit includes safety barriers for the P & T transmitters. Thus, P&T transmitters with “Ex i” certification can be interface directly to the FC I.

The EEx-e enclosure is a junction/connection box. It houses the necessary terminal blocks and is the physical link between the FGM 160 and the transducers. All communication wiring provided by the FGM 160 and power supply goes via this enclosure.

An entire EEx-d solution will be available on request. The EEx-e housing is then removed, and the terminal blocks and the FGM 160 Unit are integrated in a common EEx-d housing.

5.3 Operating the Field Computer

5.3.1 Operator Console

Operating the FGM 160 from an Operator Console connects from the FC I via a Modbus RS485 connection. According to the RS485 standard, the Operator Console can be located up to 1200 meters away from the FC I. A DCS system via Modbus RS422 or RS485 gives access to basic parameters and limited system management.
The interface is based on entering commands with corresponding values. These commands are predefined and described in detail in the User’s Manual. The corresponding value can either be a new parameter value or only a display value telling the FGM 160 to display a certain parameter or result.

5.3.2 Remote Console

An option for a NetOp server is available if desirable. NetOp is a Remote Control Software that gives access to the Operator/Service Console through a TCP/IP connection. A NetOp server installed locally in the Service Console enables full access to the system for operators off-site with a NetOp client if access is approved on-site.

This solution eliminates the demand for on-site Operator/Service Control since full access and system control is available from any location.

This solution also makes it possible for Fluenta AS to remote the system, assist with diagnostics and offer online software updates and support. Software updates for DSP, P&T and I/O can be upgraded on-the-fly.

A RS 485 to TCP/IP converter enables Fluenta AS to assist with diagnostics and support, but control of the system is not possible with this solution.

5.4 Input Signals

5.4.1 Transit Time Input Signal

The ultrasonic transducer pair supplies the FGM 160 with upstream and downstream transit time measurements, ref. section 4.2. These measurements in combination with the pressure and temperature measurements, described in section 5.4.2 and 5.4.3, form the foundation for the FGM 160 outputs described in section 5.5.

5.4.2 Pressure Input Signal

The pressure measurement is performed close to the transducers to get the correct pressure at the measuring point. The pressure measurement point is downstream of the transducers relative to flow measurement.
The pressure input signal is either in form of a 2-wire 4-20 mA signal or through HART transmitter modem. The locally mounted transmitter is either powered by the 24 VDC power supply in the FGM 160, or an external source.

5.4.3 Temperature Input Signal

The temperature probe is installed furthest away (downstream) from the measuring point to limit the effect of potential turbulence.
The FGM 160 collects data from the temperature transmitter through 4-20 mA or HART interface. The temperature transmitter is connected to the FGM 160 by 2-wire configuration. The locally mounted temperature transmitter is powered in the same manner as the pressure transmitter.

The pressure transmitter and the temperature transmitter are connected to the FGM 160 through internal barriers in the FGM 160 Field Computer. The analogue inputs are realized as floating 20 ohm resistors, through which the loop current flows. The common mode voltage range is within -10 to +24 volts with respect to the FGM 160's ground level.

5.5 Output Signals

5.5.1 Pulse/Frequency Output

The FGM 160 has 3 pulse output channels that can e.g. be configured for totalising of mass and volume.

Two of these pulse output channels can be configured as frequency output channels with a frequency range from 10Hz to 4 kHz. These outputs can be configured e.g. for mass or volume flowrate.

5.5.2 Analogue 4-20mA Output Signals

The FGM 160 has six analogue 4-20 mA output channels. Each of the six output channels can be configured to one of the following parameters:

- Standard Volume Flowrate
- Actual Volume Flowrate
- Mass Flowrate
- Density (Standard Conditions)
- Density (Actual)
- Molecular Weight
- Pressure
- Temperature
- Alarm = 4 mA (Alarm LOW)
- Alarm = 20 mA (Alarm HIGH)

5.5.3 HART Output

The FGM 160 has one analogue output channel that can be configured as a HART output interface. The HART output interface supports function code 0, 1 and 3. Refer to Fluenta AS doc. no: 72.120.306 – FGM 160 HART Interface Specification, for a detailed description of the HART interface.

5.5.4 Modbus Serial Interface

Parameters in the FGM 160 are accessible through a serial interface by using the Modbus protocol. All or just a selected range of parameters in an array can be accessed in a single read or write operation. Single precision floating-point presentation is the implemented format. Some arrays contain 'Read only' parameters. Others contain 'Read / Write' parameters.

Refer to Fluenta AS doc. no. 72.120.305 – FGM 160 Modbus Interface Specification for a full description of the Modbus interface.

6. Ultrasonic Transducers

6.1 Transducer Full Size (TFS)

The ultrasonic transducers mounted onto the flare pipe are approved for operation in Zone 0 with safety class EEx ia IIC T6. They are mounted in transducer holders that are welded on to the flare pipe at carefully selected angles, positioned with specially designed mounting jigs.

A piezo-electric crystal is mounted inside the titanium housing at the front of the transducer. When the crystal is subjected to an alternating electrical signal, it vibrates with the same frequency as the electrical signal. The crystal is attached to the front membrane of the titanium housing and this membrane vibrates with the crystal. The membrane movement generates the ultrasonic signals. When a transducer receives ultrasonic signals, the membrane vibrates and the crystal transfers this movement into an electrical signal.

Both transducers in a pair operate as transmitter and receiver. At the transmitting transducer an electrical frequency signal is converted to an ultrasonic pulse. At the receiving transducer, the signal is converted back to an electrical frequency signal, enabling the system to determine the time of travel for the ultrasonic pulse using cross correlation. The measured transit times are used to calculate the axial gas flow velocity and volume flow rate in the pipeline.

6.2 Transducer Full Size, Ball Valves

Ball valves are mounted between the full size transducer and holder to enable installation and retraction of the transducers during normal process operation. The pressure sealing is established using a tube fitting solution which after initial installation ensures that the transducer position remains constant even after the transducer have been taken out for servicing.

7. References

N/A

4.2 Flow Calculations

1. Purpose

This document lists the fundamental formulas and data used in the Fluenta Flare Gas Meter, FGM 160, to calculate flow velocity and volumetric and mass flowrate.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM Flare Gas Meter

Additional abbreviations used in this chapter are for simplicity explained in same section where used.

2.2 Definitions:

Definitions used in this chapter are for simplicity given in same section where used.

3. Flow Calculations

Formulas and data used in the FGM 160 calculations are given in the following sections.

Flow calculations performed by the FGM 160 can be derived from Figure 6.

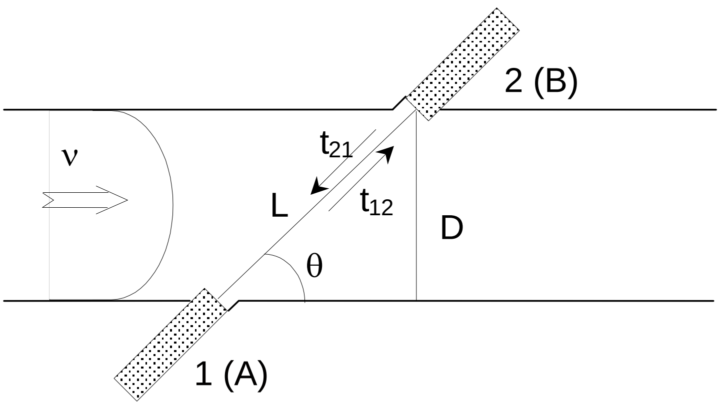


Figure 6 Sensor alignment and parameters of importance for the flow calculations.

3.1 Axial Gas Flow Velocity Calculation

$$v = \frac{L}{2\cos\theta} \cdot \frac{t_{21} - t_{12}}{t_{12} \cdot t_{21}}$$

Equation 1 Axial gas flow velocity calculation.

where:

v	=	axial velocity [m/s] of flowing medium without compensation for Reynold's number variations
L	=	distance between transducers
θ	=	angle of intertransducer centre line to axis of the pipe
t_{12}	=	transit time (sec) from Transducer 1 (A) to Transducer 2 (B) (downstream)
t_{21}	=	transit time (sec) from Transducer 2 (B) to Transducer 1 (A) (upstream)

3.2 Reynold's Number Calculation

$$\mathrm{Re} = \frac{v \cdot D \cdot P \cdot T_0 \cdot Z_0}{Kin.Visc. \cdot P_0 \cdot T \cdot Z}$$

Equation 2 Reynold's number calculation.

where:

Re	=	Reynold's number
P	=	Measured pressure in Bar A
P_0	=	1.01325 Bar A (reference conditions)
$Kin.Visc.$	=	Kinematic Viscosity (See value below)
T_0	=	288.15 K = 15 °C (reference conditions)
T	=	Measured temperature in Kelvin
Z_0	=	Compressibility factor at reference conditions
Z	=	Compressibility factor at operating conditions

$Kin.Visc.$, Z_0 and Z are operator entries (default);

$Kin.Visc.$	=	15×10^{-6} m²/s
Z_0	=	1.0 (default)
Z	=	1.0 (default)

3.3 Correction Factor Calculation

$$k = f(\mathrm{Re})$$

Equation 3 Flow profile correction factor based on Reynold's number.

where:

k	=	Correction factor used as compensation for flow profile variations, derived as Reynold's number.

k is typical in range: 0.89 – 0.96

3.4 Average Axial Gas Flow Velocity Calculation

$$\overline{v} = k \cdot v$$

Equation 4 ***Average*** **axial gas flow velocity calculation.**

where:

$\overline{v}$ = *Average* axial velocity [m/s] of flowing medium compensated for Reynold's number (flow profile) variations.

3.5 Volume Flowrate Calculation

$$Q_V = A \cdot \overline{v} \cdot \frac{P}{P_0} \cdot \frac{T_0}{T} \cdot \frac{Z_0}{Z} \cdot 3600$$

Equation 5 **Volumetric flowrate calculation, at reference conditions.**

where:

Q_v = Volume flowrate at reference conditions [Sm^3/h]
A = Cross sectional area of pipe [m^2]

3.6 Mass Flowrate Calculation

$$Q_m = Q_V \cdot (1/M) \cdot \rho_b$$

Equation 6 **Mass flowrate calculation, based on volumetric flowrate at reference conditions.**

where:

ρ_b = Calculated gas density [kg/m^3]

$$M = \frac{P}{P_0} \cdot \frac{T_0}{T} \cdot \frac{Z_0}{Z}$$

Q_m expressed related to gas flow velocity:

$$Q_m = A \cdot \bar{v} \cdot \rho_b \cdot 3600$$

Equation 7 Mass flowrate calculation, based on average axial gas flow velocity.

3.7 Density Calculation

The FGM 160 calculates the gas density and molecular weight online based on available information from the process, obtained through the ultrasonic transit time measurements and through measured line pressure and temperature.

General Density Model:
The General Density Model (GDM) is based on the relationship between known properties of hydrocarbon gases at low pressures, gas density and molecular weight. The model assumes velocity of sound (VoS), Pressure (P), Temperature (T) and R (gas constant = 8.31432 J/mol * K) to be known. The GDM is a general, "blind" model, with no pre knowledge on the gas composition of a specific installation.

Input:

Velocity of Sound (VoS)	Calculated based on ultrasonic transit time measurements.
Pressure (P)	Measured by Pressure Transmitter.
Temperature (T)	Measured by Temperature Transmitter.

Output:
- Gas Density
- Molecular Weight
- Mass Flowrate

Model Uncertainty:
Based on model evaluation, the gas density calculation model uncertainty is estimated to be ~ 2.2 %.

Total Gas Density Uncertainty (example):

Assumed uncertainty of VoS:	5.0 %
Assumed uncertainty of P:	1.0 %
Assumed uncertainty of T:	1.0 %
Total Gas Density Uncertainty:	~ 9.4 %

4. References

N/A

4.3 Cable Description

1. Purpose

The following sections describe the most commonly used cables in Fluenta Flare Gas Meter, FGM 160 system.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM 160	Fluenta Flare Gas Meter, model FGM 160
TFS	Transducer Full Size

2.2 Definitions:

N/A

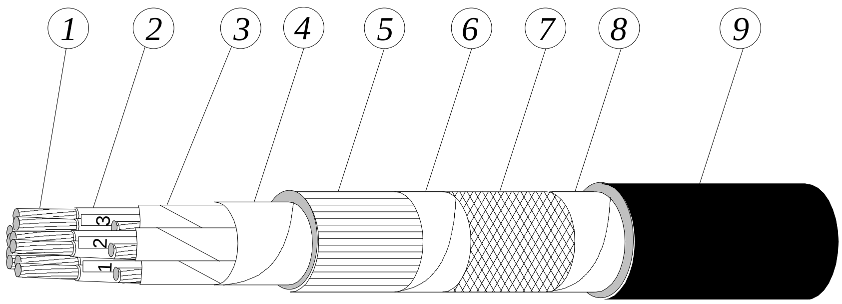
3. Field Computer Power Cable Specification

The cable presented below is the most commonly used cable within the FGM 160 system. The cable utilized is a RFOU(i). Other alternatives are available on request.

3.1 General Properties

- Flame retardant cable with individual screen.
- Design guidelines according to IEC 60092-3.
- Fixed installation for instrumentation, communication, control and alarm systems in both EX- and safe areas.
- Meets the mud resistant requirements in NEK606.

3.2 Cable Construction



		Code Letter	
1.	Conductor		Tinned, annealed, stranded copper.
2.	Insulation	R	EP-rubber
3.	Twinning		Colour coded cores twisted together and wrapped with polyester tape.
4.	PET-tape		
5.	Bedding	F	Flame retardant halogen-free thermoset compound.
6.	PET-tape		
7.	Armour	O	Tinned copper wire braid.
8.	PET-tape		
9.	Outer sheath	U	Flame retardant halogen-free and mud resistant thermoset compound.

3.3 Range and Dimensions RFOU (i)

No. of pairs/triples and conductor area		**Conductor diameter approx.**	**Insulation thickness**	**Diameter over bedding**	**Diameter overall**	**Weight of cable**
mm²		**mmØ**	**mmØ**	**mmØ**	**mmØ**	**kg/km**
1 pair	0,75	1,10	0,80	9,0 ±1,0	11,5 ±1,0	200
2 pair	0,75	1,10	0,80	11,5 ±1,0	15,0 ±1,0	341
4 pair	0,75	1,10	0,80	13,5 ±1,0	17,5 ±1,0	500
7 pair	0,75	1,10	0,80	16,5 ±1,0	20,5 ±1,5	706
8 pair	0,75	1,10	0,80	19,0 ±1,0	23,0±1,5	847
12 pair	0,75	1,10	0,80	21,5 ±1,5	26,0 ±1,5	1150
16 pair	0,75	1,10	0,80	24,0 ±1,5	29,0 ±1,5	1378
19 pair	0,75	1,10	0,80	25,0 ±1,5	29,5 ±1,5	1543
24 pair	0,75	1,10	0,80	29,5 ±1,5	35,0 ±2,0	1984
32 pair	0,75	1,10	0,80	33,0 ±2,0	39,0 ±2,0	2540

3.4 Technical Data

Operating voltage	250	V
Max. operating conductor temperature	85	°C

3.5 Electrical Characteristics

Capacitance approx.	90	nF/km
Inductance approx.	0.75	mH/km
Resistance at 20°C max.	24.8	Ohm/km

3.6 Fire Tests Certifications

Flame retardance	IEC 60332-3/A
Halogen-free properties	IEC 60754-1,2
Flame retardance	IEEE 45/383

3.7 Gland Recommendation for Flame Retardant Cables

Ex (d) - Glands with seal on both inner and outer sheath
Ex (e) - Glands with seal on outer sheath only

4. Transducer Cable Specification: Radox cable

The coupling between the Field Computer (FGM 160) and the transducers is provided by a Radox GKW–LW/S EMC cable.

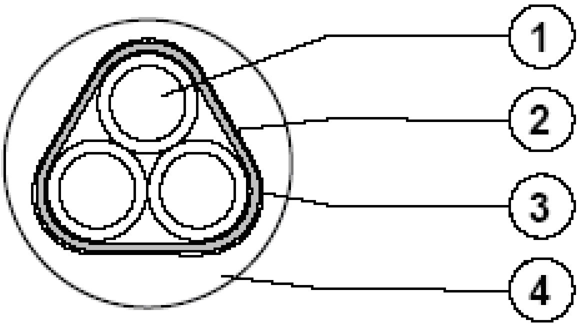
Optionally it may be that the coupling is done by a RFOU(c) cable (see chapter 5). This is the case whenever Fluenta will have performed maintenance and exchanged existing TFS transducers with new ones. The respective Radox cable is at the same time upgraded with Fluenta's new and more flexible RFOU(c) cable. This counts from February 2011.

The main properties of the Radox cable are listed below.

4.1 General Properties

Excellent high temperature, low temperature, ozone, diesel oil and weathering resistance, zero halogen, flame retardant, easily strippable, flexible, excellent screening properties.

4.2 Cable Construction



1.	Cores GKW-LW	Conductor: flexible tin plated copper Dual wall insulation: GKW P/ GKWHP Colour: n x white: all cores sequentially numbered
2.	EMC-screen	Tin plated copper braid optimised
3.	Wrapping (optional)	Plastic tape
4.	Jacket	Radox GKW S, colour: black

4.3 Technical Data

Voltage U_0/U	600/1000	VAC
	900/1500	VDC
Test voltage 50 Hz, 5 min	3500	V
Max. conductor temperature conditions	+ 120	°C
Min. operating temperature	- 40	°C
Min. bending radius free installation	5 x diameter	
Min. bending radius fixed installation	3 x diameter	
Conductor cross-section	0,75	mm^2
Number of leaders	6	
Weight kg/100m	8,5	kg

4.4 Fire Tests Certifications

The cables pass the following fire tests:

Vertical flame spread of bunched cables		BS4066-3, modified to BS6853
Smoke density		BS 6853 annex D
Toxic fume	R ≤ 1,0	BS 6853 annex B
Vertical flame spread of a single cable		DIN EN 50265-2-1
Vertical flame spread of bunched	Category C	DIN EN 50266-2-4

cables		
Vertical flame spread of bunched cables	Category D	DIN EN 50266-2-5
Smoke density		DIN EN 50268-2
Vertical flame spread of bunched cables		NF C32-070 test 2
Smoke density	smoke index ≤ 5	NF X10-702-2
Toxic fume	smoke index ≤ 5	NF X70-100
Vertical flame spread of a single cable		IEC 60332-1, EN 50625-2-1
Vertical flame spread of bunched cables	Category C	IEC 60332-3-24, EN 50266-2-4
Amount of halogen acid gas	0 mg/g	IEC 60754-1, EN 50267-2-1
Corrosivity of combustion gases		IEC 60754-2 EN 50267-2-3
Smoke density		IEC 61034-2, EN 50268-2

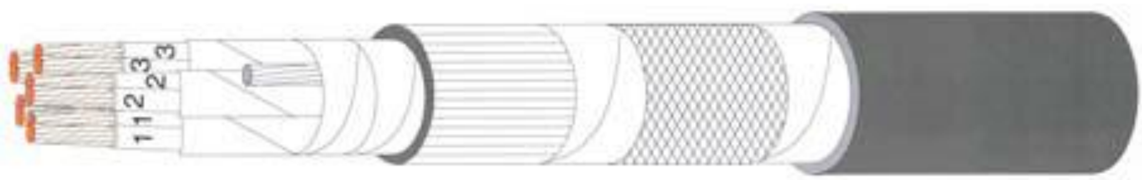
5. Transducer Cable Specification: RFOU(c) cable

As mentioned in chapter 4 the RFOU(c) cable applies after existing TFS transducers were exchanged with spare ones. The coupling between the Field Computer (FGM 160) and the transducers will then be provided by a RFOU(c) cable.

5.1 General Properties

- Flame retardant cable.
- Design guidelines according to IEC 60092-376(2003-05).
- Fixed installation for instrumentation, communication, control and alarm systems in both EX- and safe areas.
- Meets the mud resistant requirements in NEK TS 606:2009.

5.2 Cable Construction



	Code Letter	
Conductor		Tinned, annealed, stranded circular copper.
Insulation	R	EP-rubber

Twinning		Colour coded cores twisted together and wrapped with polyester tape.
PET-tape		
Inner covering	F	Flame retardant halogen-free thermoset compound.
PET-tape		
Armour	O	Tinned annealed copper wire braid.
PET-tape		
Outer sheath	U	Flame retardant halogen-free and mud resistant thermoset compound.

5.3 Range and Dimensions RFOU (c)

No. of pairs/triples and conductor area mm²	Conductor diameter approx. mmØ	Insulation thickness mmØ	Diameter over bedding mmØ	Diameter overall mmØ	Weight of cable kg/km
4 pair 0,75	1,10	0,60	11.5 ±0.8	15 ±0.8	390

5.4 Technical Data

Operating voltage	250	V
Max. operating conductor temperature	90	°C
Min. installation temperature	-20	°C
Min. bending radius free installation	8 x D	
Min. bending radius fixed installation	6 x D	

5.5 Electrical Characteristics

Capacitance approx.	100	nF/km
Inductance approx.	0.67	mH/km
Resistance at 20°C max.	26.3	Ohm/km

5.6 Standards Applied

Design		IEC 60092-376 (2003-05)
Conductor		IEC 60228 class 2
Insulation		IEC 60092-351
Sheath		IEC 60092-359
Flame Retardant		IEC 60332-1
Flame Retardant		IEC 60332-3-22
Halogen Free		IEC 60754-1,2
Low Smoke		IEC 61034-1,2

6. References

NA

5. HANDLING, INSTALLATION AND STORAGE

5.1 Preservation, Packing, Unpacking and Storage Procedure
5.2 Installation & Hook-Up Instructions
5.3 Hazardous Area Installation Guidelines

5.1 Preservation, Packing, Unpacking and Storage Procedure

1. Purpose

The purpose of this procedure is to describe Fluenta AS's preparation for shipment and transport to ensure that the equipment will be correctly treated from the time of leaving Fluenta AS's works, throughout any transport period, until it has reached its final destination. Details on unpacking, inspection and storage procedures are also given.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM	Flare Gas Meter
TFS	Transducer Full Size

2.2 Definitions:

N/A

3. General

All Fluenta Flare Gas Meter (FGM 160), produced and supplied by Fluenta, will be preserved, packed, marked and shipped according to this procedure.

4. Preservation

All items will be free of dirt, oil, grease and other contaminants before preservation and packing commences.

4.1 General

The following describes how Fluenta AS will preserve the equipment supplied to the customers. The equipment will be preserved at all stages from leaving Fluenta AS's works, until it is finally placed in service.

4.2 Field Equipment

- The FGM 160 Field Computer will be shipped in the FGM 160 Field Computer transportation box.
- All carbon steel machined/unprotected surfaces will be protected with Tectyl 506 protection oil or similar.
- Flanges will be protected using plastic cover or plywood.
- Ultrasonic transducers will have extra protection to prevent any damage to the sensor head.

4.3 Control Room/Local Instrumentation Room Equipment

All equipment will be protected by bubble plastic or similar and packed in wooden cases.
Tags stating the number of desiccants used will be attached to each package

5. Marking

All items will be marked with labels showing tag numbers and if necessary, description.

6. Packing and Dispatch

The instrument items will be packed separately in wooden cases. The cases are cushioned for protection and all cases will be filled with foam pellets or creased paper. All packages will be marked with the relevant handling instructions, unpacking instructions and shipping marks.

The following shipment marks will be used:

P.O. No.	:	<XXX>
MMT No.	:	<XXX>
Item	:	<XXX>
Supplier	:	<XXX>
Pack. No.	:	<XXX> of <XXX>
Size	:	<XXX>
Gross	:	<XXX> kg
Country of origin	:	Norway

The packing list (one for each package) will contain the following information:

- P.O. No:
- MMT No.
- Name of equipment/material.
- Item, tag or code no.
- Quantity and description of goods.
- Size and Gross weight.
- Indication complete or partial delivery.
- Point of delivery.
- Origin of goods.
- HS Number.
- Shipping marks.

The shipping documents will be located as follows:

Inside each package:

- Preservation, packing, unpacking and storage procedure (this document).

Outside each package in a waterproof envelope:

- 1 Original of each packing list.

With carrier accompanying delivery:

- 1 Originals of packing list.
- 2 Originals of Commercial/Proforma Invoice.
- Additional Documentation as Material Certificates and Certificate of Origin.
- Airwaybill/Bill of lading.

7. Unpacking

Initial preservation has been carried out on the equipment before leaving Fluenta AS. Due to the delicate nature of the equipment, great care should be undertaken when handling both unopened and opened crates.

The receiver should check that all items have been received according packing lists. All plastic film and other cover materials should be removed before the equipment is taken into use. Make sure that all "Cortec" have been removed before start-up.

8. Inspection

The equipment shall be inspected for damage and cleanliness at receipt at construction site. Any damage shall be reported without undue delay to the project and the supplier. No repair work should be attempted without prior inspection and approval from the supplier.

9. Storage and Handling

If the equipment is going to be stored before installation and commissioning the following actions should be carried out:

- Replace all corrosion inhibitors (Cortec or similar).
- To be stored indoor.
- The equipment is preserved for 12 months storage. The preservation status should be inspected and if necessary preservation maintenance should be carried out. The equipment should be inspected every 6 weeks.
- The equipment should be stored under the following conditions:

Temperature:	+ 15 °C to + 30 °C
Relative Humidity:	< 45 %

The package contains **DELICATE INSTRUMENTS** and must be **HANDLED WITH GREATEST CARE**.

The items should be stored in their original packing until they arrive at the final destination.

10. References

N/A

5.2 Installation & Hook-Up Instructions

1. Purpose

The purpose of this procedure is to provide a traceable point-by-point installation guideline for the Fluenta Flare Gas meter, Field Computer (FGM 160) system. This document provides details on the different options that are available to the FGM 160 system, the installation of the base system, and the optional configurations. The optional configurations include the two types of transducer, possible upgrade from previous Fluenta Flare Gas Meters, and the different interfaces available from the Flow Computer to the Plant Control System. The procedure also provides a means to establish an "Installation and Hook-Up Record" to document the installation.

2. Abbreviations / Definitions

2.1 Abbreviations

FGM	Flare Gas Meter
TFS	Transducer Full Size

2.2 Definitions

Metering Spool Section	– A section of pipe that has the transducer, pressure, and temperature holders already mounted.
Cold Tapping	– Mounting the transducer, pressure, and temperature holders on a section of the flare pipe which has been shut off from the flare system.
Hot Tapping	– Mounting the transducer, pressure, and temperature holders on a section of the flare pipe which is an active part of the flare system.

3. General

The FGM 160 system supplied from Fluenta is designed to work with no major preparation. Due to the complexity and the required accuracy of the measurements it is mandatory to obtain a very high degree of precision and care during all phases of the installation.
This procedure includes the required steps from unpacking to commissioning. After unpacking and inspection of the received goods has been carried out, the system should be ready for installation. The description of the installation of the system is divided in subsections as follows:

- Transducer/ Probe installation.
- FGM 160 Field Computer installation.

Note that warranty for the transducers only applies if certified personnel install the transducers. Certified personnel include Fluenta service engineers, service engineers of our agents who have received proper training and operators who have attended and completed Fluenta's respective Training Course.

4. Unpacking

4.1 Inspection of Goods

Installation of the equipment supplied by Fluenta must never occur without the inspection of the supplied goods carried out first. This should be performed according to the instructions and tasks described in:

FGM 160 Preservation, Packing, Unpacking and Storage Procedure, Fluenta Doc.no.: 62.120.002 [1].

The important issue is to verify the goods with the packing list and inspect for damages caused by transportation. Save packing material for storing and reshipping of the equipment, if required.

4.2 Ex-Classification Marking

Make sure that the FGM 160 is certified for the area and hazardous zone it is intended to be installed in. The Ex-Classification marking of the equipment is described in:

FGM 160 – Hazardous Area Installation Guidelines, Fluenta Doc.no. 62.120.006 [2].

4.3 Equipment Information

The FGM 160 requires +24 VDC power supply (nominal). If 24 VDC is not available, an optional 110-230 VAC/24 VDC converter can be supplied by Fluenta.

For more detailed equipment information and equipment ratings, please refer to: FGM 160 – Hazardous Area Installation Guidelines, Fluenta Doc.no. 62.120.006 [1].

4.4 Manufacturer Information

The FGM 160 Flare Gas Meter is manufactured by Fluenta AS:

Visiting address:
Sandbrekkeveien 85
Nesttun, Bergen
Norway

Telephone/Fax:
Telephone: +47 55 29 38 85
Fax: +47 55 13 21 60

Mail address:
P. O. Box 115, Midtun
N-5828 Bergen
Norway

E-mail addresses:
Sales: sales@fluenta.com
Support: support@fluenta.com

5. Transducer/Probe Installation

5.1 Installation of Transducer Holders

There are three alternatives for mounting the transducer holders. The first is using a metering spool piece that have the transducer, pressure, and temperature holders already installed at a mechanical workshop. The second is what is referred to as "Cold Tapping", where the holders are installed on a section of pipe that is shut off from the flare system. The third option is what is referred to as "Hot Tapping", where the holders are mounted onto a flare pipe that is active. The metering spool piece is assembled in a mechanical workshop, and "Cold Tapping" and "Hot Tapping" are done by welders under the supervision of Fluenta personnel.

5.1.1 Space Requirements

The space requirements around the pipe vary for transducer models and pipe diameters. Those will be covered in the following sections. The transducers must be mounted, regardless of the pipe diameter or transducer model, on a straight section of pipe. The length of this straight section must be at least 15 times the diameter of the pipe. The nearest upstream disturbance must be at least 10 times the diameter of the pipe away from the center of the metering section, and the nearest downstream disturbance must be at least 5 times the diameter of the pipe long. These distances are illustrated in Figure 7. For installations that cannot meet these requirements Fluenta should be contacted as this may have an effect on the measurement uncertainty. As this product is a fiscal measurement system this effect should be evaluated.

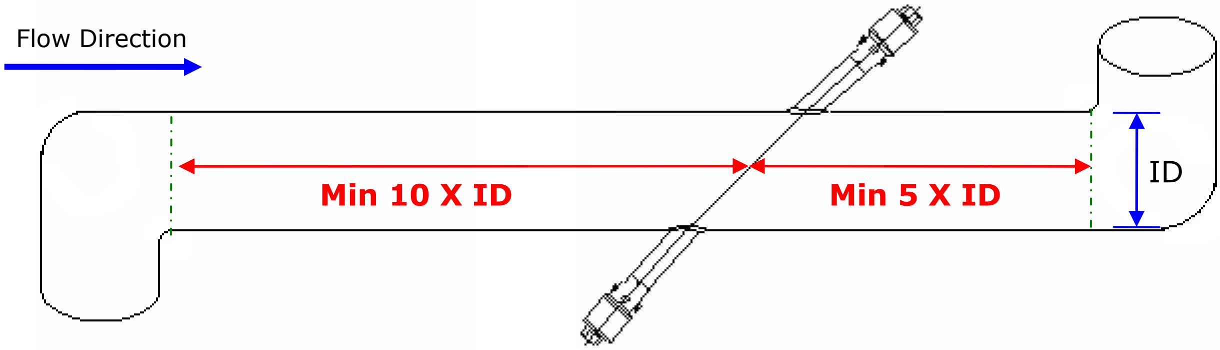


Figure 7: Fluenta's minimum straight upstream and downstream distances to disturbances.

5.1.1.1 Space Requirements for the Transducer Full Size, TFS

There are two different space requirements for the TFS installation. This is due to the fact that for pipes with a diameter 10" and less, the mounting angle for the upstream holder is 48°, and for the downstream holder the angle is 42°. Pipes with diameters from 12" to 72" have a mounting angle of 45° for both.

Table 2 shows the distances required and Appendix I has a schematic of the installation for both sets of diameters. Note that the Perpendicular Distance is the distance that the mounted transducer assembly protrudes from the side of the pipe, and the Length is the length of the assembly without regard to the pipe.

There might be the case that on older installations with TFS transducers the installation angles are 42°/48° for 6” to 20” spools and 45°/45° for 22” – 72”.

Table 2: The space Requirements for Transducer Full Size, TFS. with updated installation angles

	Pipe Size	
	6" – 10"	**12" – 72"**
Perpendicular Distance		
Operational upstream perpendicular distance	525 mm	500 mm
Operational downstream perpendicular distance	475 mm	500 mm
Retracted upstream perpendicular distance	770 mm	730 mm
Retracted downstream perpendicular distance	690 mm	730 mm
Length		
Operational	700 mm	700 mm
Retracted	1,030 mm	1,030 mm

Table 3: The space Requirements for Transducer Full Size, TFS. with former installation angles

	Pipe Size	
	6" – 20"	**22" – 72"**
Perpendicular Distance		
Operational upstream perpendicular distance	525 mm	500 mm
Operational downstream perpendicular distance	475 mm	500 mm
Retracted upstream perpendicular distance	770 mm	730 mm
Retracted downstream perpendicular distance	690 mm	730 mm
Length		
Operational	700 mm	700 mm
Retracted	1,030 mm	1,030 mm

5.1.1.2

5.1.1.2 Space Requirements for the Temperature and Pressure Transmitters

The pressure and temperature transmitters must be mounted no closer than 2xID downstream of path between the transducers (this does not apply to certain pre fabricated spool pieces) and not more than 1000mm. The temperature transmitter's intrusive design requires that it be mounted as the furthermost transmitter. These transmitters should be mounted on top of pipe if the pipe is horizontality oriented or at a 90° angle to the transducers if the pipe is vertically oriented. These positions are chosen due to good engineering practice, with a more practical motive. This is due to the possibility that there is liquid in the pipe, and mounting on the top of the pipe reduces the chance that they will be harmed by an accumulation of liquid. Figure 8 illustrates the minimum distance and orientation of the pressure and temperature transmitters.

The ultrasonic transducers for the FGM 160 have built-in temperature sensors (for production date before December 2010; they are not implemented any longer). These temperature sensors are primarily used for temperature monitoring purposes, and are normally not used for process temperature input.

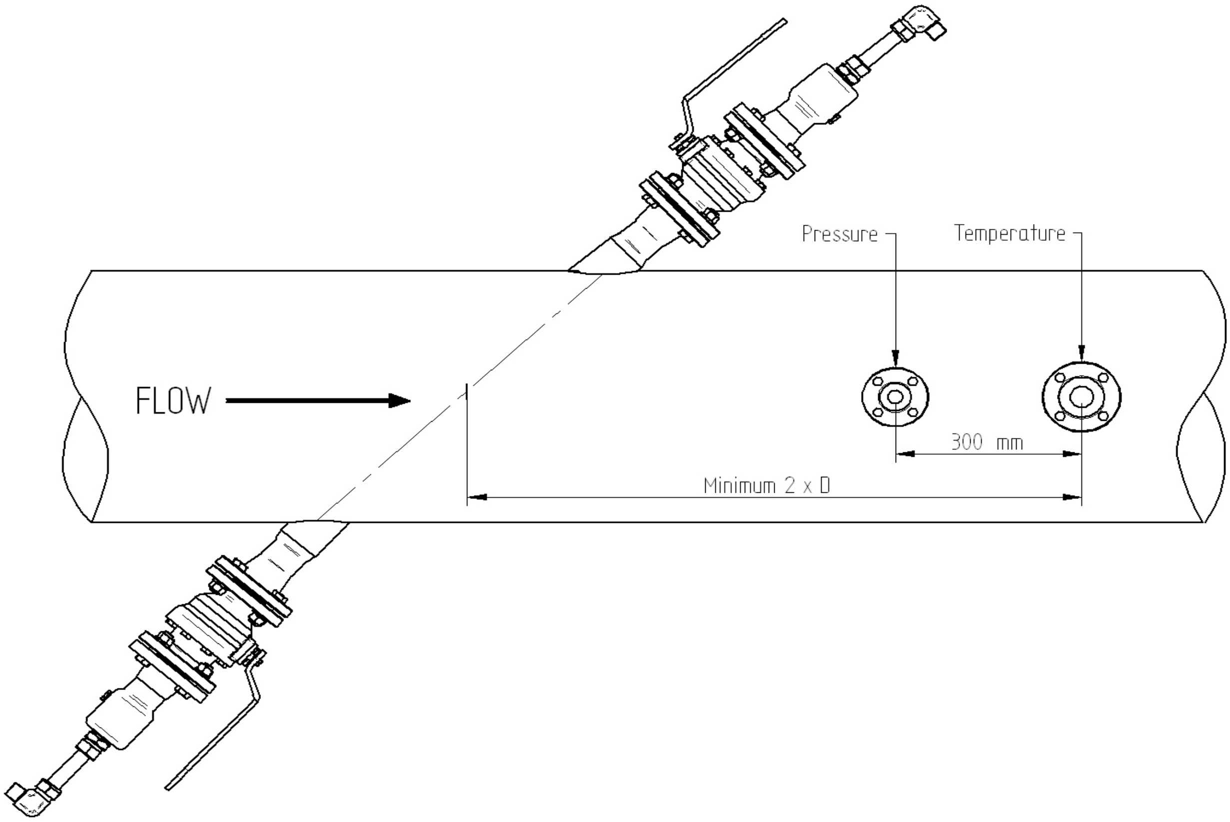


Figure 8: Distance requirements for the pressure and temperature transmitters.

5.2 Mounting the Transducer Holders

There are three ways to mount the transducer holders. The first is by mounting a Spool piece which is a pre-fabricated pipe with all of the holders (transducer, pressure, and temperature) already mounted. This pre-fabricated spool piece is inserted into the existing flare pipe system. The second option is to perform what is referred to as Cold Tapping which means that the transducer holders are mounted directly onto a flare pipe which has been temporarily removed or cut off from the flare system. The last option is what is referred to as Hot Tapping which means that the transducer holders are mounted directly onto a pipe that is being used by the flare system. Due to the dangerous nature of this option, it is performed by a third party with a specialty in this area.

5.2.1 Orientation

5.2.1.1 Horizontal Flare Pipe

The optimal orientation of the transducers on the flare pipe depends on whether the flare pipe is horizontal, vertical, or inclined at a certain angle. If the transducer holders are to be installed on a horizontal section of the flare line, the transducers should be horizontally oriented as shown left in Figure 9. The reason for this is that there may be fluid accumulation in the flare pipe, and if the transducers are orientated any other way than horizontal, fluids might accumulate in the lower transducer holder. This must then be drained to ensure the functionality of the meter.

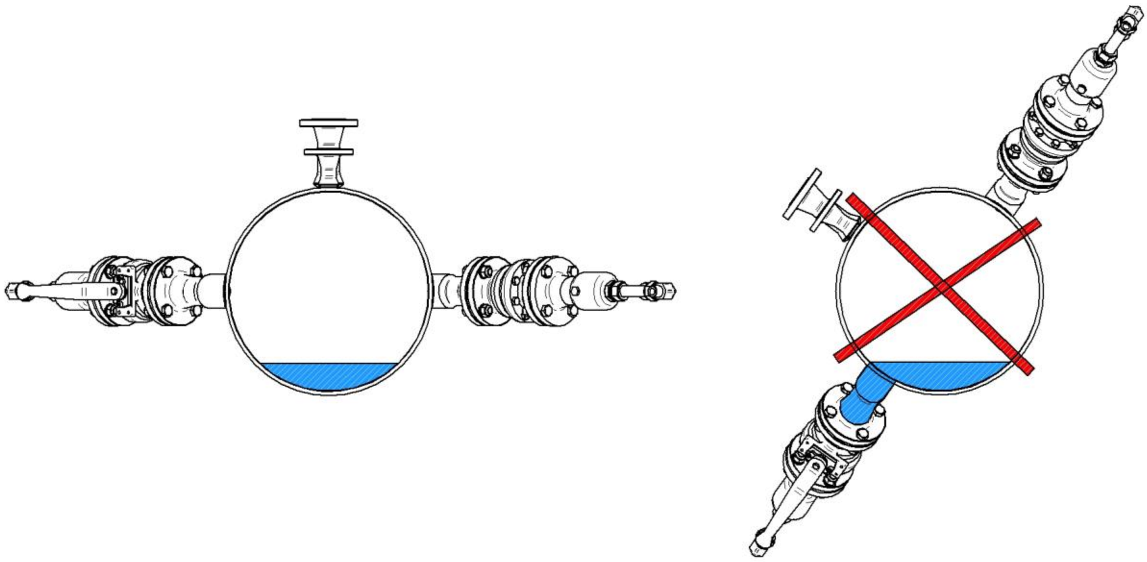


Figure 9: The preferred and non-preferred orientation for horizontal pipe installation.

5.2.1.2 Vertical Flare Pipe

The transducer holders may also be mounted on a vertical section of flare pipe. The orientation of the transducer holders in this case does not matter, as the possibility of fluid filling the upstream transducer holder is the same regardless of the orientation. In this case the transducer holders may be mounted in a position that suits space and access requirements. If this is the orientation that is chosen then the upstream transducer holder must be periodically checked for liquid accumulation and if necessary emptied. Figure 10 shows the transducer holder orientations for a vertical pipe. A continuous drain system may be installed by leading the fluids back into the pipeline at a lower point of the flare stack.

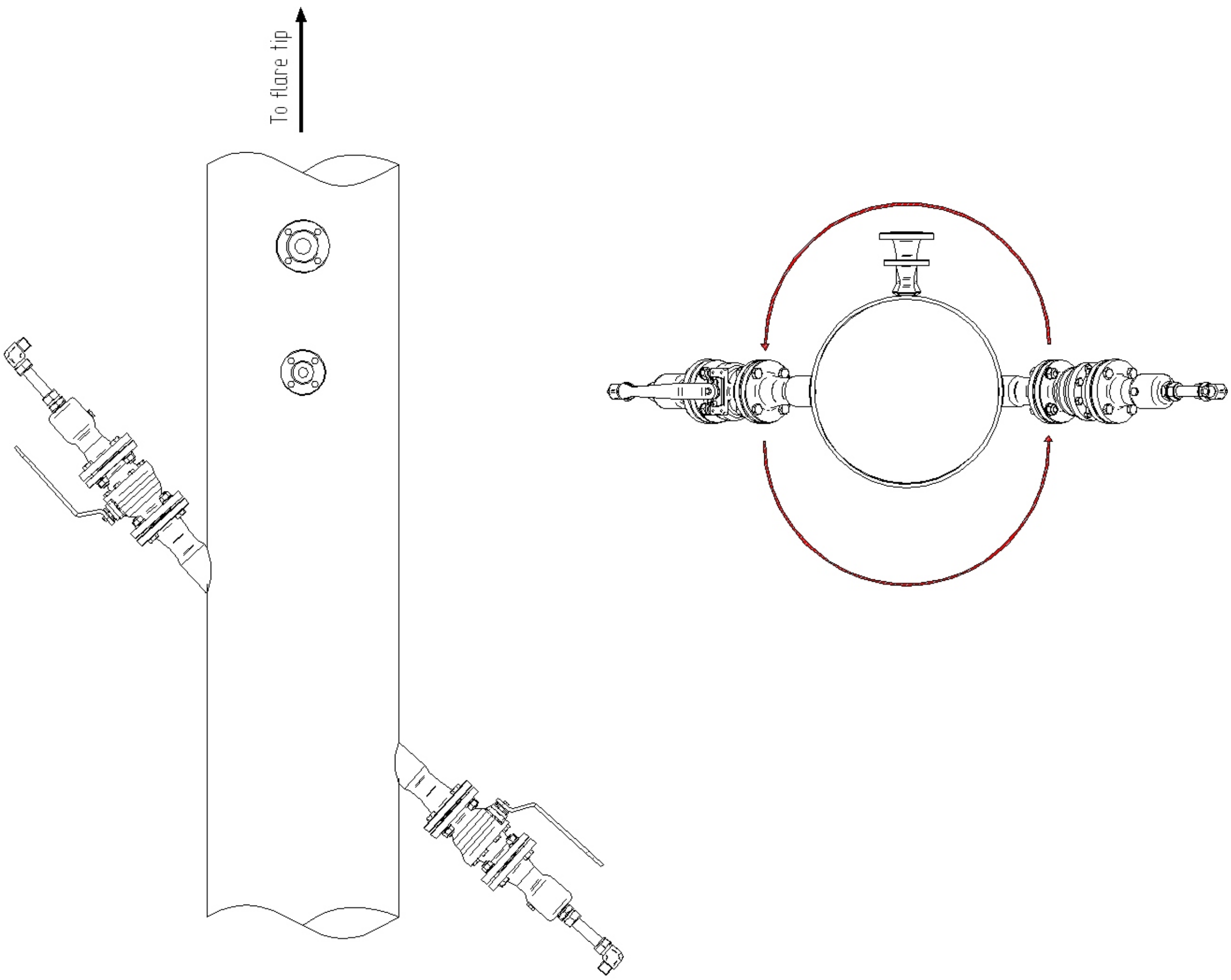


Figure 10: Vertical flare boom with the transducer holders and transducers installed. The orientation of the transducers is irrelevant for installation on a vertical pipe run.

5.2.2 Cold Tapping

Installation of transducer holders must always be supervised by trained Fluenta personnel, or personnel specially trained by Fluenta. Before installing the transducer holders on the pipe, the correct placement of the spot marks must be ensured. There are numerous ways this can be done.

First we need to look at were the spot marks are supposed to be placed. Looking at Figure 11, note that the horizontal distance between spot A and spot B is the same as the outer diameter of the pipe (applies only to 45° installations).

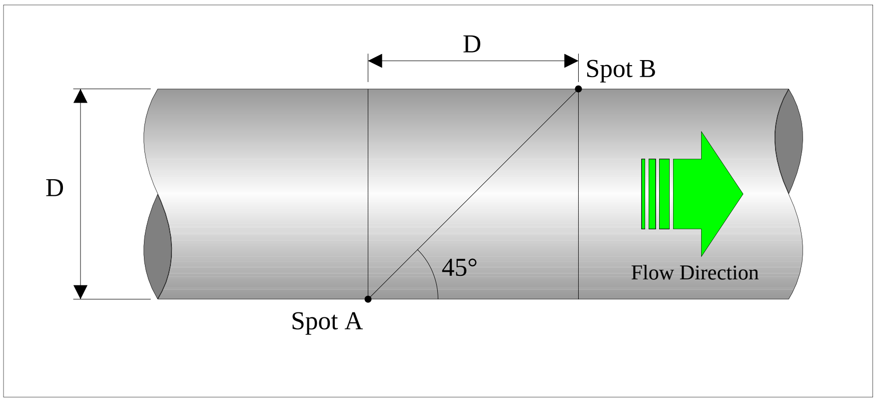


Figure 11

The first thing to do is to find the centerlines on the pipe. Note that the centerlines are exactly opposite each other on the pipe, ref. Figure 12. Always ensure that the centerlines are placed accurately by measuring the distance between them, both on the upper and lower circumference. The measured lengths should be the same.

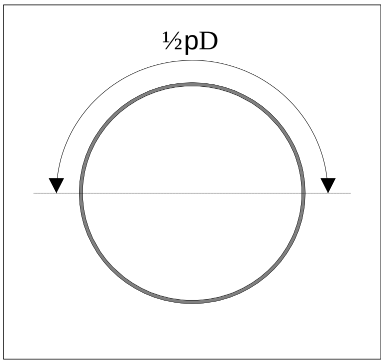


Figure 12

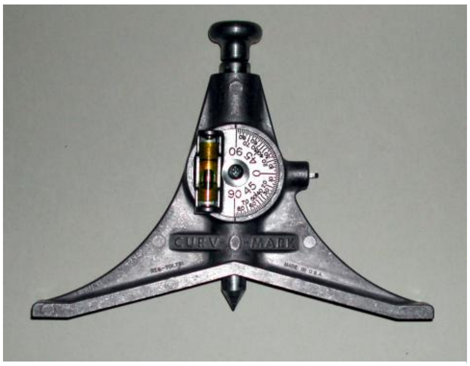


Figure 13

If the pipe is horizontal, use the Curv-O-Mark contour marker to find the centerlines on each side of the pipe, ref. Figure 13. Remember to turn the contour marker and set a second spot, to avoid problems in regards to misalignment of the grade scale.

If the pipe is vertical or inclined at a certain angle , other means of finding the centerlines must be applied. Confer with the pipe fitter or welder, as they usually have the tools and experience needed to help you.

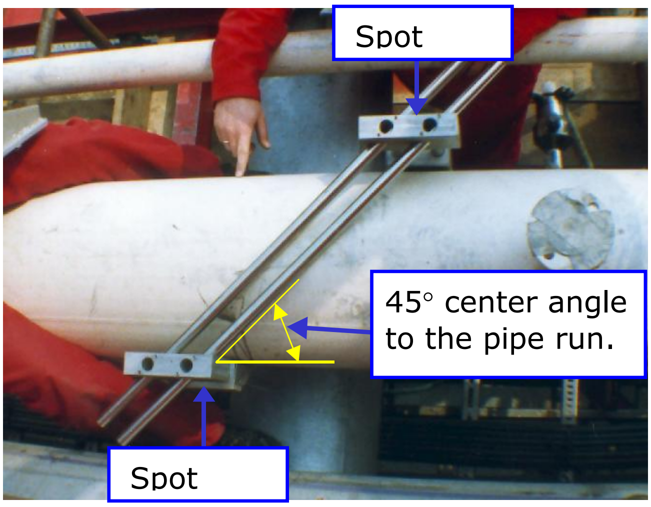


Figure 14: Marking jig used for positioning of the transducer holders.

Fluenta recommends using the special marking jig, ref. Figure 14.
Adjust the marking-jig to fit the pipe-diameter. Clamp it to the pipe and mark the centre-position for both transducer holders. If no marking jig is available, other means of finding and marking the spots

must be used. We will describe two methods, but there are numerous ways this can be done.

One proven method is to use a marking band. After the centerlines are marked and their position verified, use the labeling band to mark a line round the pipe, placed at the first spot (spot A), ref. Figure 15. Then, on the other side of the pipe, measure the distance to the second spot (spot B). It is also a good idea to mark another line around the pipe at spot B, as this will help when placing transducer holder B.

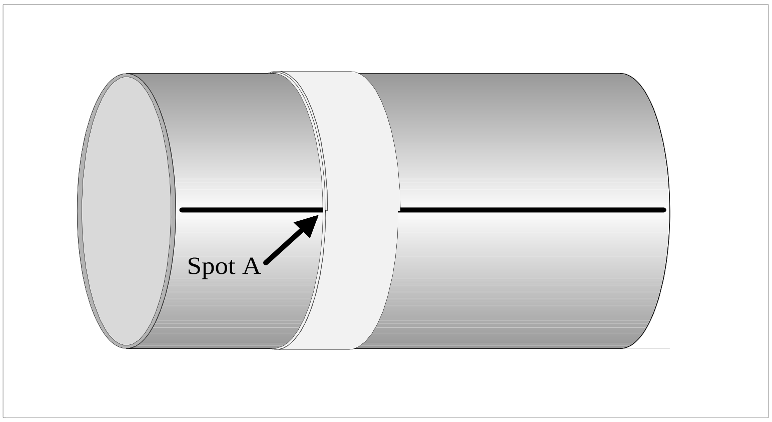


Figure 15: Marking a line around the pipe using a marking band

A second and just as good a method is to use a paper, the width of the diameter of the pipe and length equal to circumference. Attach the paper to the pipe and verify that the ends meet exactly. Take the paper off the pipe and fold it in two. Mark the fold, and reattach the paper to the pipe. Spot A will then be were the paper ends meet and spot B will be were you marked the fold on the other side of the pipe. See Figure 16 and Figure 17.

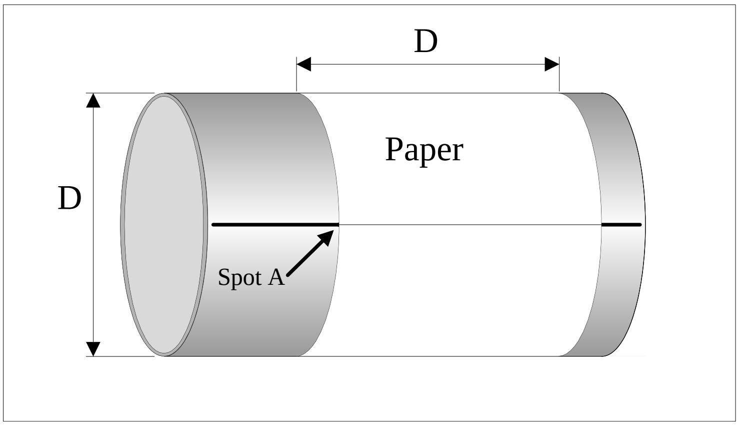


Figure 16: Attach the paper around the pipe

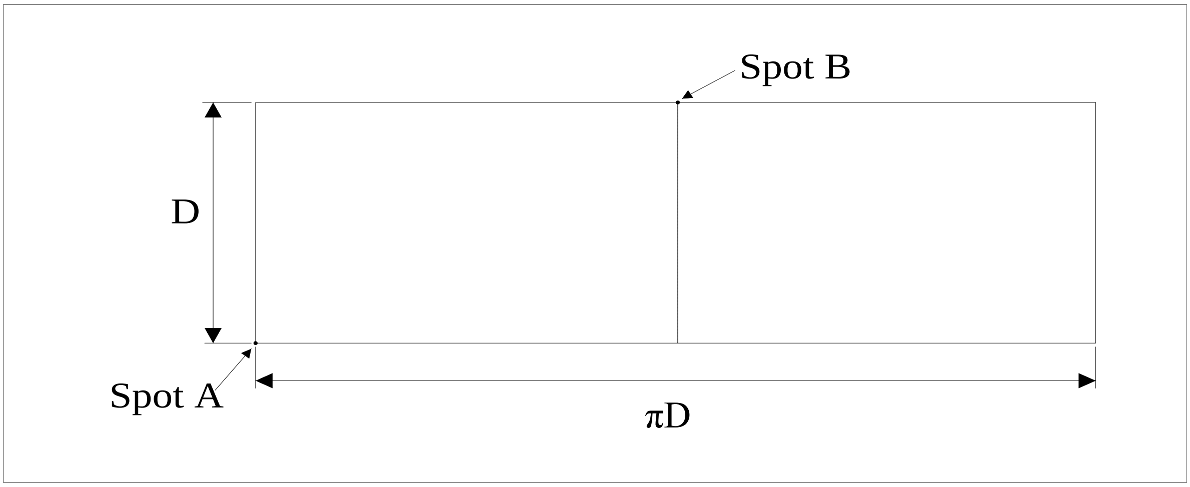


Figure 17: Fold the paper in two. Mark the fold. This will give you spot B.

Remove the marking-jig and clamp the welding-jig to the pipe and mount the transducer holder. Mark the hole for the sensors on the pipe wall following the inside rim of the transducer holder when they are mounted in the welding-jig. Repeat for the other transducer holder. The holes can now be cut following the marked line on the pipe-wall. Sharp edges and burrs must be avoided. A hole with smooth edges is required. Do not make the hole to small, follow the inside rim.

After the holes are made, ensure that the inner edges are grinded to be smooth, and bevelled the correct way. Ref. Figure 18. Before the welding starts, the groove angle must be grinded on the holders. Normally the holders must be taken off the welding-jigs for grinding/adjustment to get the right opening and joint, ref. Figure 19.

Adjust the gap between pipe and transducer holder until it is correct. This is done to get a satisfactory welding connection. Usually the spacing will be between 2mm and 4mm, depending on the welder's preference. Note that as you raise the transducer holder from the pipe, it must be moved backwards with the same amount (applies only to 45º installations), see Figure 20.

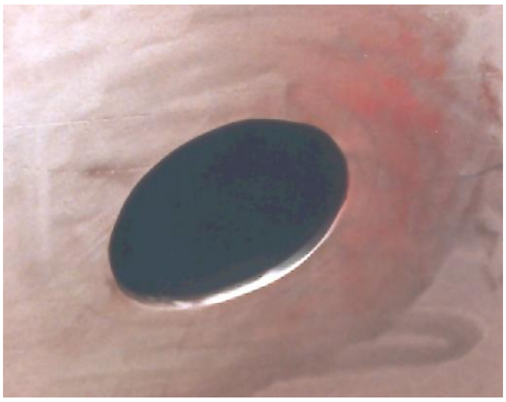


Figure 18

Figure 19

When the transducer holders are grinded and the holes have been made, get the welding-jig in the right position and connect the transducer holder. The transducer holder can now be tacked to the pipe. Usually the welder will use three or four tacks. Ensure that there is enough space to insert the transducer. Use the sighting tool to verify this. The tool should be able to be inserted without any friction or obstructions.

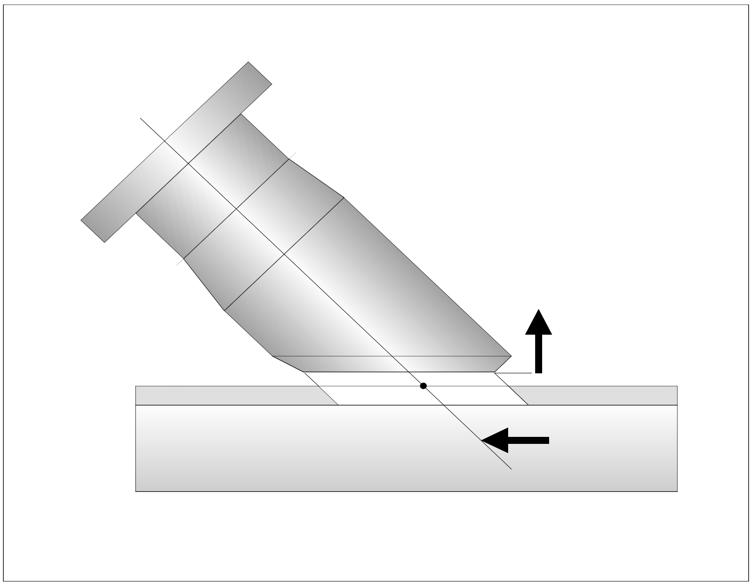


Figure 20: Note that as you raise the transducer holder, you must also move it backwards to keep the centering correct.

The next step is to mount the second transducer holder. Repeat the procedure, but to verify the exact location/position, you must use the special measuring/view tool.

It is assumed that the buyers welding procedure is approved before the work starts and that the welding is performed by certified welders.

When correct alignment of both transducer holders are ensured (see section 5.25.2.3), the welder can weld and fill out both transducer holders. Be aware that as the welding progresses, the transducer holders can be pulled off their angles by the welding process. Therefore it is necessary to pay close attention during the welding, regularly checking the angles with the digital electronic level.

Figure 21: Welding jig and transducer holder.

Figure 22: Transducer holder welded to the pipe.

This job needs a skilled welder as precision and accuracy is demanded to get the transducer holders welded into their right positions. The transducer holders are welded onto the pipe according to the buyers welding procedure. Next step will be NDT and final approval of the welding. The welding-jigs can be dismounted when the transducer holders are properly connected to the pipe as shown in Figure 22.

5.2.3 Using the Sighting Tool

There are two types of sighting tool, one for each angle set. The first type, shown in Figure 25, is for transducer holders mounted at a 45° angle. There are two tools in a set, one fits snugly in each transducer holder. Each of the tools has a hole in the center.

Figure 24: The sighting tool for the 42°/48° transducer holders

Figure 25: The sighting tool for 45° transducer holders.

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Figure 23: The stop washer for the sighting tool for the 42°/48° transducer holders.

The second type of sighting tool is made for transducer holders that are mounted on pipes with a diameter of 10" and less and with 42°/48° transducer holders, ref. Figure 26. This set of tools use the path of light for verification like the first. As the transducer holder's mounting angles are not equal, these tools require some adjustments before they can be used. The set comes with a pair of stop washers, shown in Figure 23. The tool must penetrate the transducer holder to the same depth as the transducer.
Figure 24: The sighting tool for the 42°/48° transducer holders

Figure 25: A 45° sighting tool mounted in a transducer holder.

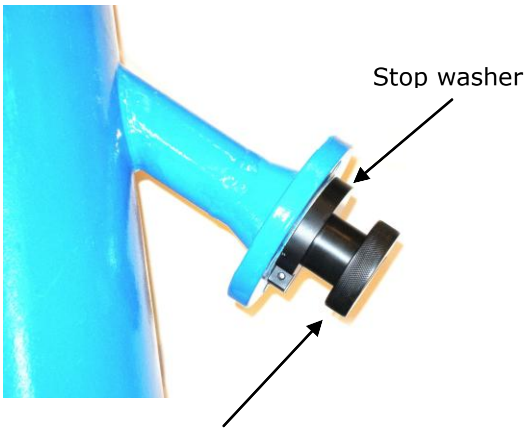


Figure 26: A 42°/48° sighting tool with stop washer mounted in a transducer holder.

When using the sighting tool for pipes that have a diameter greater than 10”, insert the sighting tool into the transducer holder so that the flange of the sighting tool is flush with the flange of the transducer holder. This is shown in Figure 25.

When using the sighting tool for pipes that are 10” and less, use the measurement from the special tool in described in section 5.3.1 to find the correct depth for the transducer. This depth should be the same for the sighting tool. Measure from the narrow end of the sighting tool and tighten the stop washer at that position. Insert the sighting tool so that the stop washer is flush with the flange on the transducer holder, this is shown in Figure 26. There is a groove in the head of this type of sighting tool shown in Figure 27. Align one sighting tool with the pipe, and rotate the other until the light is visible. Adjust the sensor holder so that the circle of light is

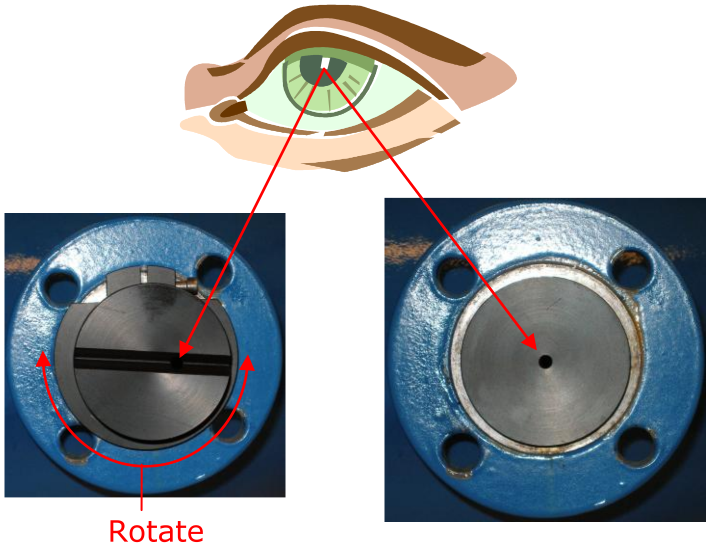


Figure 27: Look through the holes on the sighting tool. Rotate the sighting tool on the left to get a correct alignment.

seen as described below.

When the transducer holders are properly aligned and the sighting tools are inserted, it is possible to see a perfect circle of light when looking through the hole in one of the sighting tools, shown in Figure 28. If there is not enough ambient light, it may be necessary to shine a light source through the hole in the opposite sighting tool.

Figure 28: A good alignment.

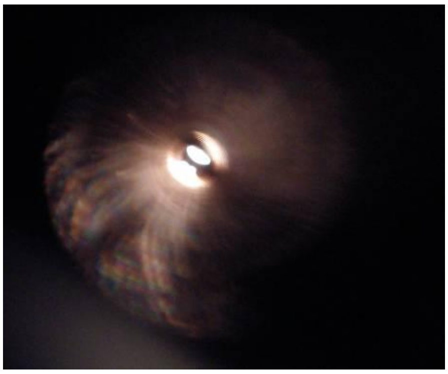


Figure 29: A bad alignment.

5.2.4 Hot Tapping Transducers Full Size, TFS

If hot tapping is needed, use the same procedure described in Cold Tapping but do not drill the pilot holes. When the welding of the transducer holders has been performed and the ball valves are mounted, connect the hot-tapping equipment to the 2" ball valve. Open the ball valve and drill the hole. The hole should be as close to 49.3 mm as possible, but care should be taken to avoid damage to the ball valve. If possible, use a 49 mm drill. Do the drilling carefully so that a hole without sharp edges can be obtained.

5.3 Mounting the Ultrasonic Transducers

5.3.1 Determining the Correct Position for the Transducers

Fluenta will use a special gas proof measuring tool to find the correct position for the transducers, as shown in Figure 30. The method is shown in the figure below. This is done on site during installation of the transducers and due to the fact that the entire length, including ball valves and gaskets, is measured. The transducer is thereafter positioned correctly.

Figure 30: The gas proof measuring tool.

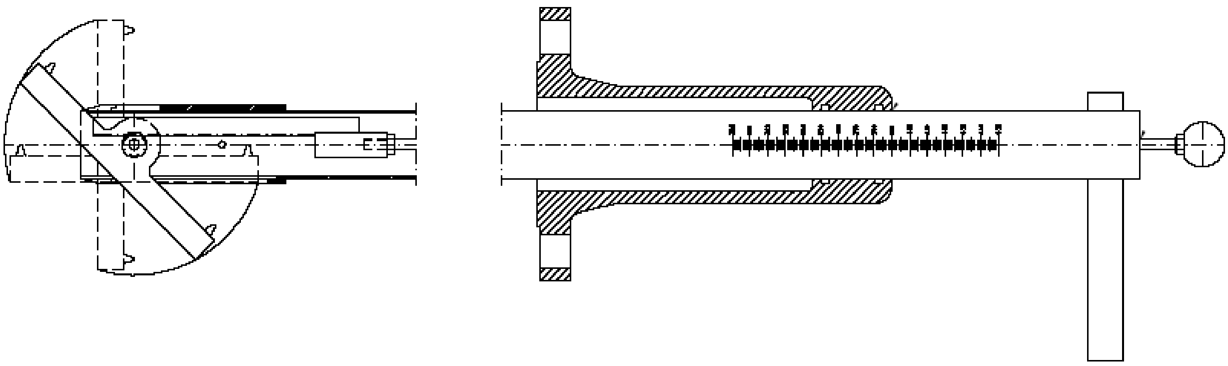


Figure 31: A schematic of the gas-proof measuring tool.

5.3.2 Insertion of the Transducer Full Size (TFS)

When the transducer holders and ball valves are installed the ultrasonic transducers may be inserted. This shall ONLY be done by personnel certified by Fluenta. If this is a first time installation, the transducer holder should be checked for liquid and drained prior to installation.

NOTE:
During transducer installation the power to FGM 160 must be turned OFF!

Verify that the installed ball valves are gas tight (no gas leaks). This should be done by the on-site personnel - using a gas monitoring device. Measure and adjust the installation depth of each transducer, which is set by fastening the A-lock lock-ring. Mount the transducer/ packbox. Open the ball valve, and push the transducer all the way in, until meeting the A-lock locker ring. Fasten the A-lock nut to the transducer packbox.

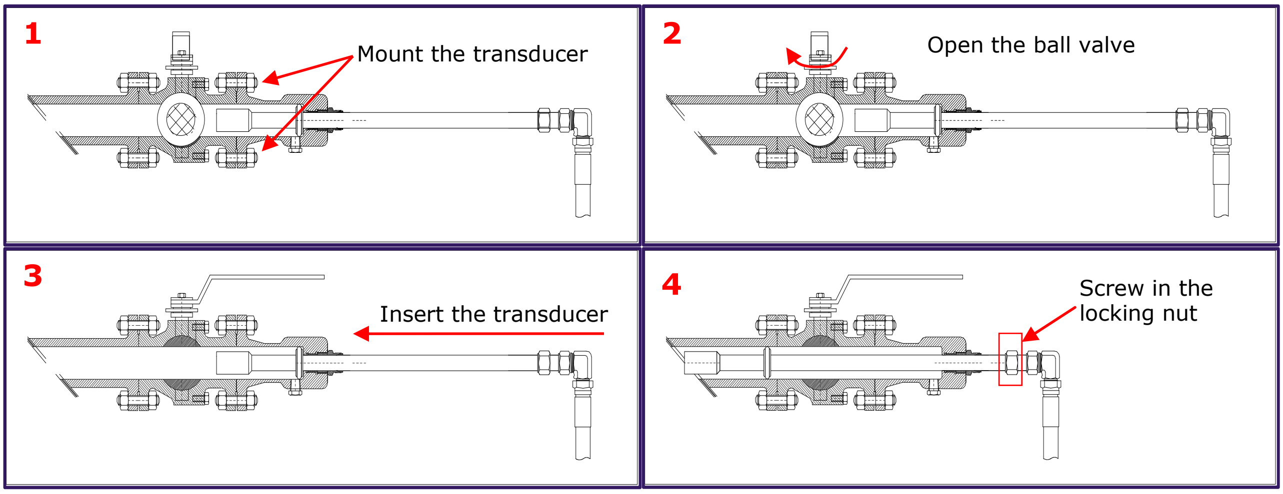


Figure 32: Mounting the Transducer Full Size.

6. Field Computer Installation

In order to reduce signal loss and maintain signal quality, the length of the signal cables should be kept as short as possible. Thus the FGM 160 (Ex-d/e Enclosure) must be mounted close to the spool piece/ transducers. The FGM 160 has lugs that enable easy mounting on either a separate frame or on top of the spool piece by brackets.

6.1 The Field Computer Mounting Brackets

The field computer can be mounted on existing infrastructure, or a custom mounting bracket. The custom mounting bracket frame comes in four versions. The first is shown in Figure 33 (a), and includes legs for a free standing mount, as well as two brackets for mounting a separate AC to DC converter in an Ex-d housing. The bracket shown in b) is the same, except it does not include a mounting bracket for an AC to DC converter. The mounting bracket in (d) shows a bracket that mounts onto the

existing infrastructure. The bracket in c) shows the same bracket as (d) with a bracket for an AC to DC converter.

a)

b)

c)

d)

Figure 33: The FGM 160 Field Computer mounting bracket versions.

6.2 Electrical Wiring

Power and signal cables between the FGM 160 and the local equipment room should be pulled and ready for termination before the installation starts. The routing and preparation of the cables is not normally part of Fluenta's scope of work.

External wiring is to be carried out according to:

FGM 160 - Field Wiring Diagram, Fluenta Doc.no.: 77.120.504 [3].

Power source should not be connected until verification of supply voltage has been performed. Main fuses should not be inserted at any stage of the installation phase

All cables should be connected to the terminals in the Ex-e enclosure of the FGM 160.

The blue terminals are IS (Intrinsically Safe) and are connected to the field computer through internal IS barriers. The gray terminals are not connected to an IS barrier, and are meant for signals between the field computer and safe area equipment and systems.

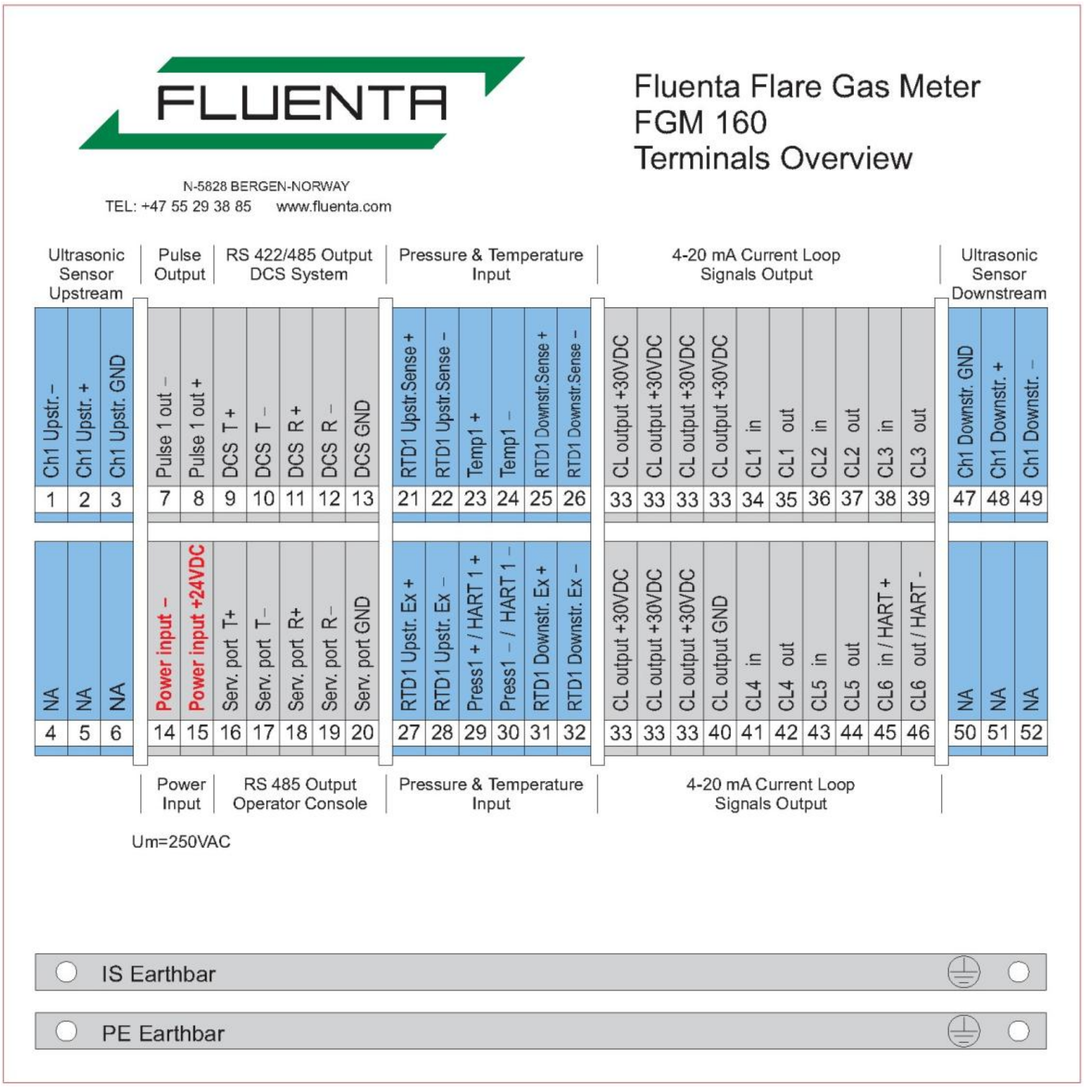


Figure 34: Ex-e enclosure terminals overview.

6.2.1 Cable Preparations

The below described steps should be carried out at both ends of the cables. However the installation of glands is not applicable for the Local Equipment Room.

- Verify the labelling/tag name on the cable.
- Verify whether the cable is “megged” or not.
- Cut the cable to a length that allows slack.
- Pull the cable through its respective gland, and make sure that the cable gland is of the required type and size.
- Terminate and secure the cable and cable gland according to instructions for the specific cable gland.
- Strip and terminate the conductors and screen according to good workmanship.
- If the cable is not “megged”, it should be carried out at this point.
- The conductors and screens should also be checked for continuity

6.2.2 Power Cable

The FGM 160 requires a 24 VDC power supply (ref. section 5.24.3 Equipment Information). Keep the twisting of the conductor pair and route the conductors to the power input terminals (ref. Figure 34). If applicable, terminate the screen to the PE Earthbar.

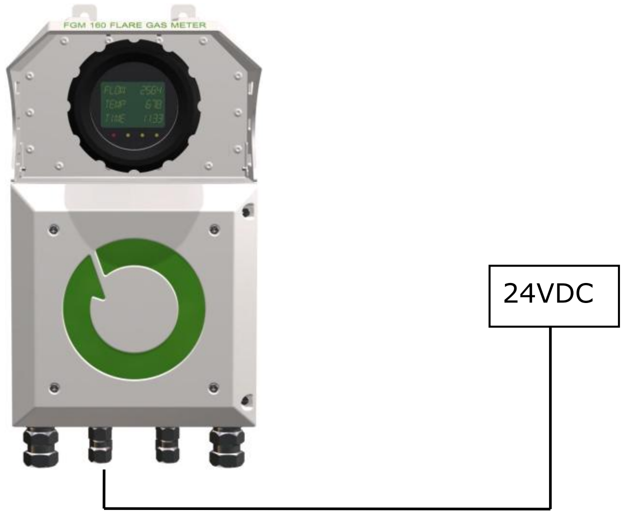


Figure 35: Power to the FGM 160.

6.2.3 Ultrasonic Transducer Cables Radox

The ultrasonic transducer cables are already prepared from the Fluenta workshop. These cables should be handled with care.
Verify the labelling/tag name on the cable. Pull the cable through its respective gland; make sure that the cable gland is of the required type and size. Secure the cable and cable gland.
It is recommended that the cable between the FGM and the transducers is kept as short as possible, 3 meters is supplied as a standard. If this is not possible to accomplish, the cable length should not exceed 10 meters. For other lengths than standard, Fluenta must be notified.

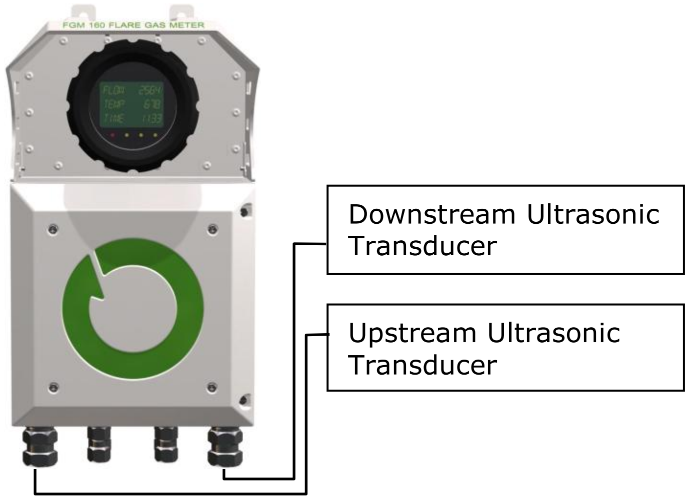


Figure 36: Connecting the Ultrasonic Transducers to the FGM 160.

The ultrasonic transducers should be connected to terminals 1 and 2 for the Upstream sensor, and terminals 48 and 49 for the Downstream sensor, ref. Figure 37. The cable screen must be terminated to the sensor GND terminals; terminal 3 for the Upstream sensor and terminal 47 for the Downstream sensor.
Note that the ultrasonic sensor cables also provide signals to the built-in RTDs in the sensors. These wires must be connected to the corresponding RTD terminals; 21, 22, 27 and 28 for the Upstream sensor, and 25, 26, 31 and 32 for the Downstream sensor.
Keep the twisting of the conductor pairs when connecting to terminals.
All conductors of the prefabricated transducer cables are labeled according to the signal names of the Ex-e terminals (ref. Figure 37)

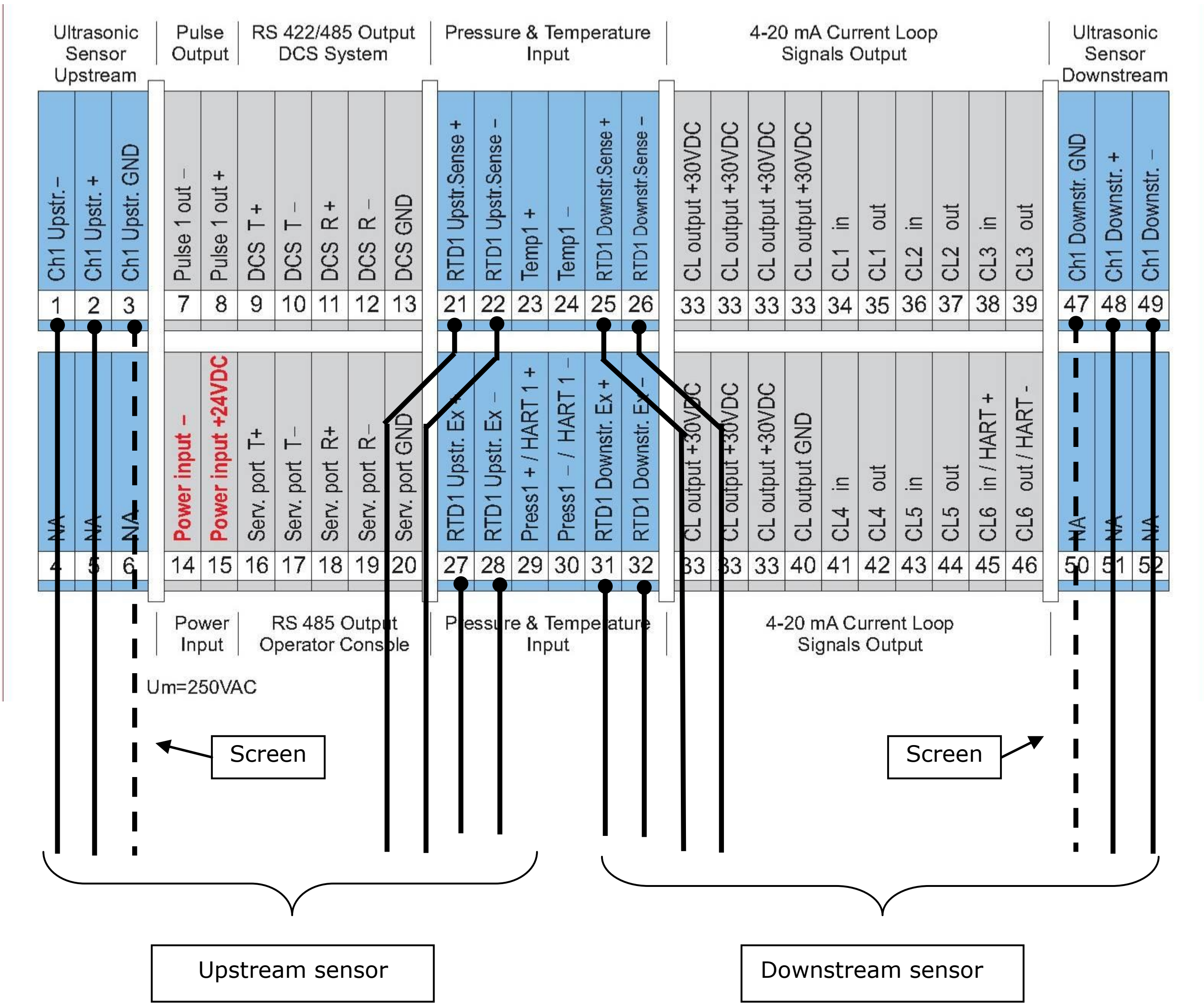


Figure 37 – Connection details for ultrasonic sensors and RTD.

6.2.4 Ultrasonic transducer cables RFOU(c)

Note: The following only counts for cable upgrades in the case of exchanging transducers.
The ultrasonic transducer cables are already prepared by the Fluenta production. These cables should be handled with care.
Verify the labelling/tag name on the cable. Take off the existing Radox cable, install the lemo plugs incl. Teflon ring (M25->M27) and re-connect resp. cabling (see below).

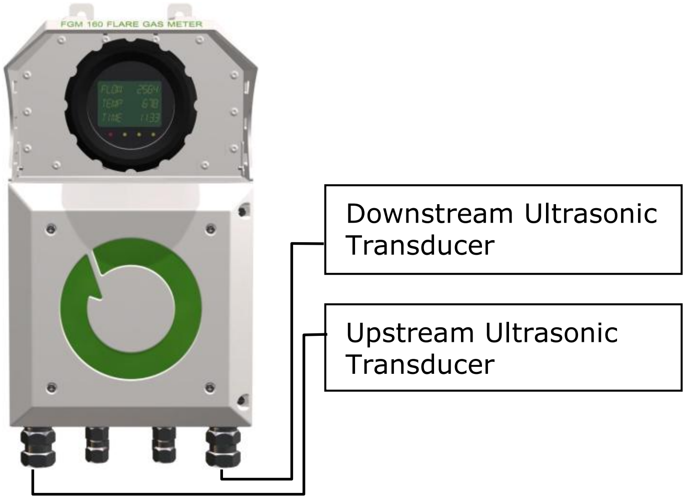


Figure 38: Connecting the Ultrasonic Transducers to the FGM 160.

The ultrasonic transducers shall be connected to terminals 1 and 2 for the Upstream sensor, and terminals 48 and 49 for the Downstream sensor, ref. Figure 37. The cable screen must be terminated to the sensor GND terminals; terminal 3 for the Upstream sensor and terminal 47 for the Downstream sensor.
Keep the twisting of the conductor pairs when connecting to terminals. All conductors of the prefabricated transducer cables are labeled according to the signal names of the Ex-e terminals (ref. Figure 37).

When all cables are connected to the connection panel, plug the RFOU(c) cables into the resp. lemo plugs on the Ex-e enclosure.

Note that the RFOU(c) ultrasonic sensor cables do not provide signals to the built-in RTD's in the TFS sensors. Therefore there is no wiring necessary. RTD measurements are usually not used for input into process measurement.

It is recommended that the cable between the FGM and the transducers is kept as short as possible, 3 meters is supplied as a standard. If this is not possible to accomplish, the cable length should not exceed 10 meters. For other lengths than standard, Fluenta should be contacted.

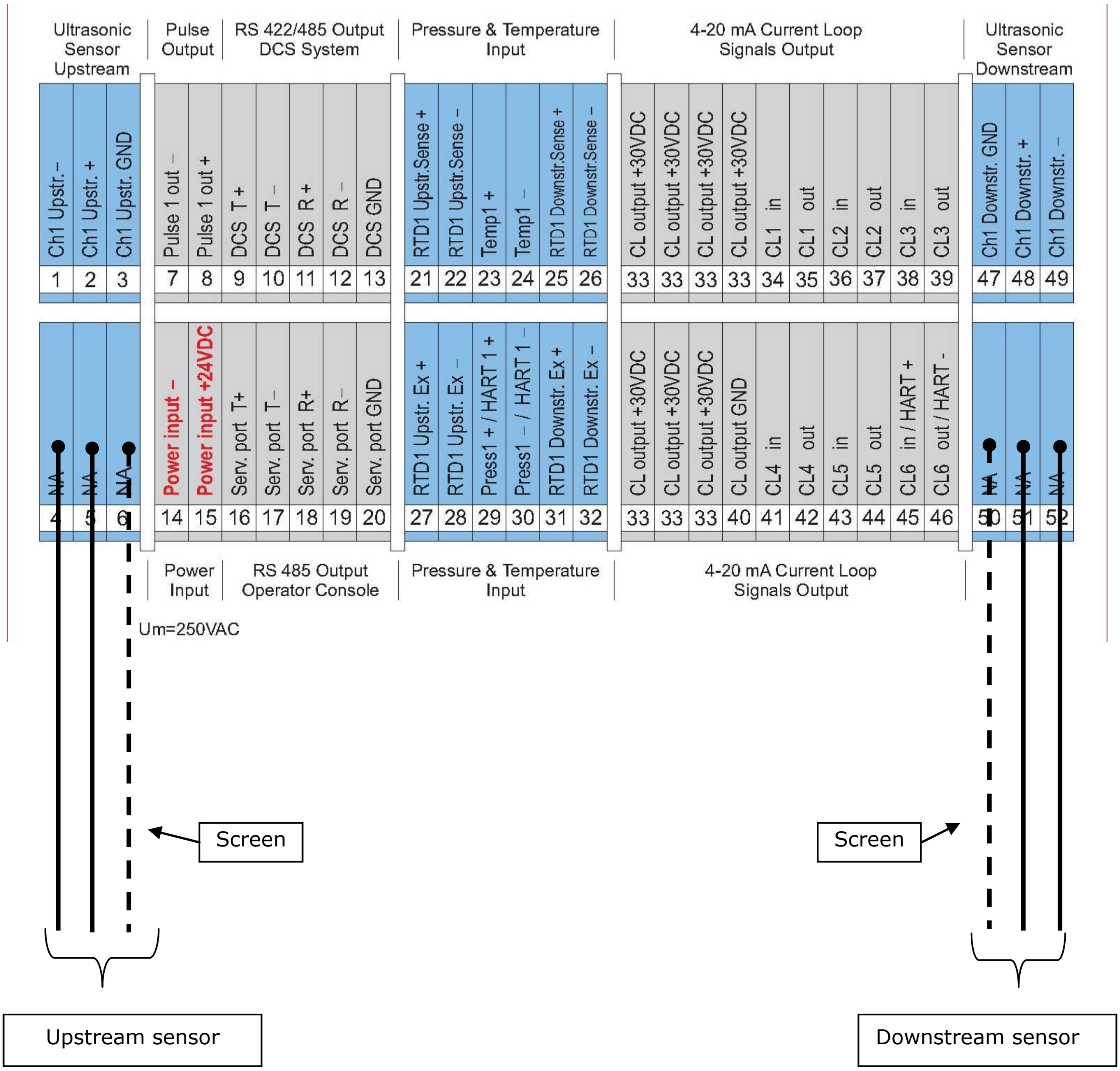


Figure 39 – Connection details for ultrasonic sensors with RFOU(c) cable.

6.2.5 Connecting the Pressure and Temperature Transmitters

Pressure and temperature transmitters shall be connected directly to the connection terminals in the Ex-e enclosure, no barriers are required, as these are built-in in the IS Barrier module within the FGM 160. For detailed information regarding the built in barriers and the optional grounding wire shown in Figure 40, please refer to: FGM 160 – Hazardous Area Installation Guidelines, Fluenta Doc.no. 62.120.006 [2].

The FGM 160 can interface either to 4-20 mA current loop transmitters or HART transmitters. Depending on the transmitter interface to the FGM 160, a connection described in figures below should be used. Up to four HART transmitters can be

connected to the HART input terminals, e.g. if condition based maintenance scheme is utilized with double or dual transmitters.

The pressure and temperature inputs at the FGM 160 are always configured as active current loop inputs (i.e. the pressure and temperature transmitters are always powered from the FGM 160 field computer).

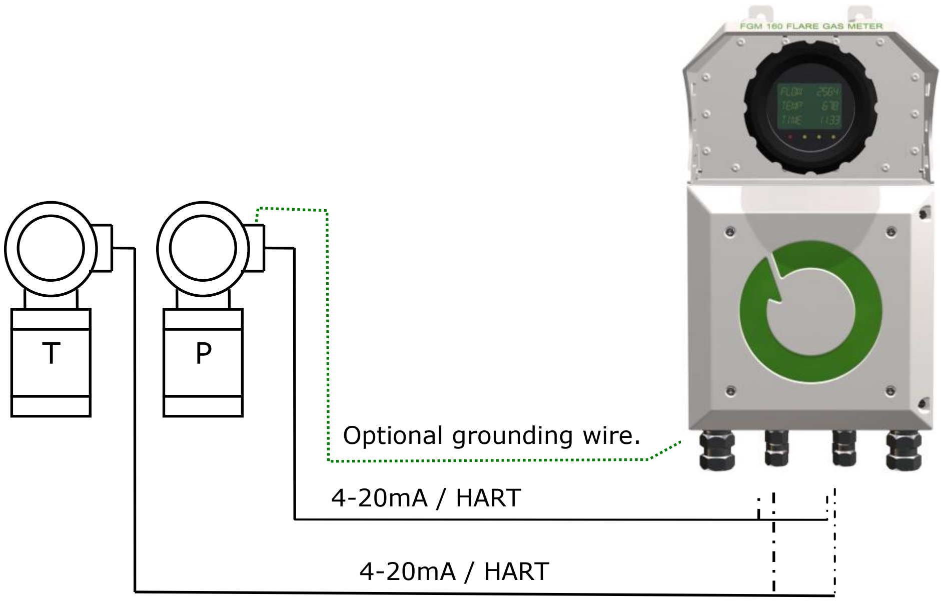


Figure 40: Pressure and temperature transmitter hook-up.

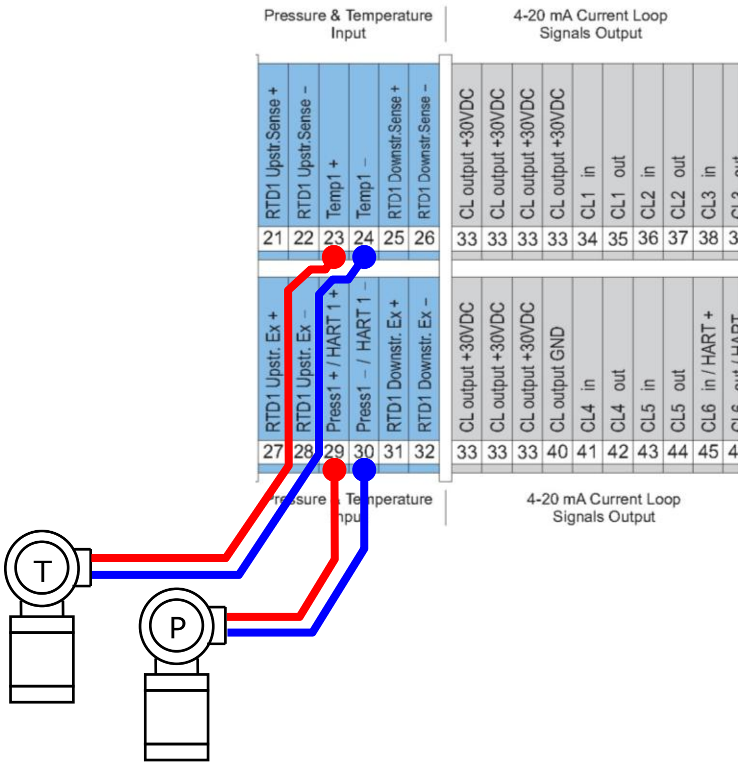


Figure 41 – FGM 160 – 4-20 mA pressure and temperature transmitter connections.

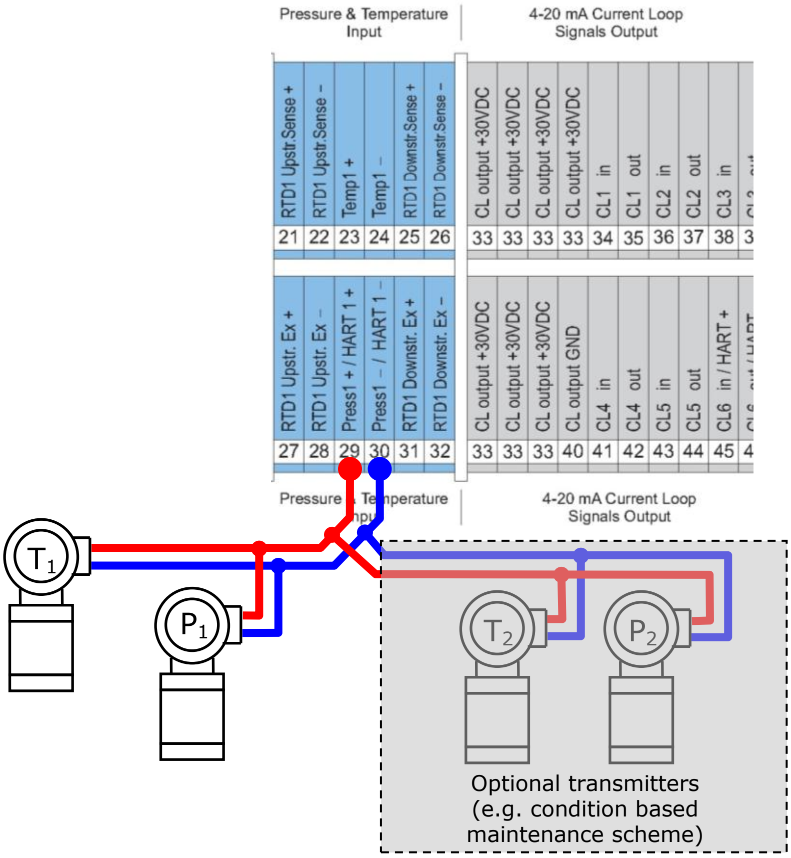


Figure 42 – Pressure and Temperature HART transmitter connection.

6.2.6 Control Room and Data Cables

The FGM 160 Flow Computer can be connected to the control room in several different ways. These allow the DCS or SCADA software in the control room to communicate with the FGM 160 Flow Computer. The following are the connection options:

- DCS port, Modbus protocol (RS-485)
- Three (3) 4-20 mA, with additional three (3) as option.
- HART interface (optional).
- One (1) Pulse, Frequency or Level output (optional).

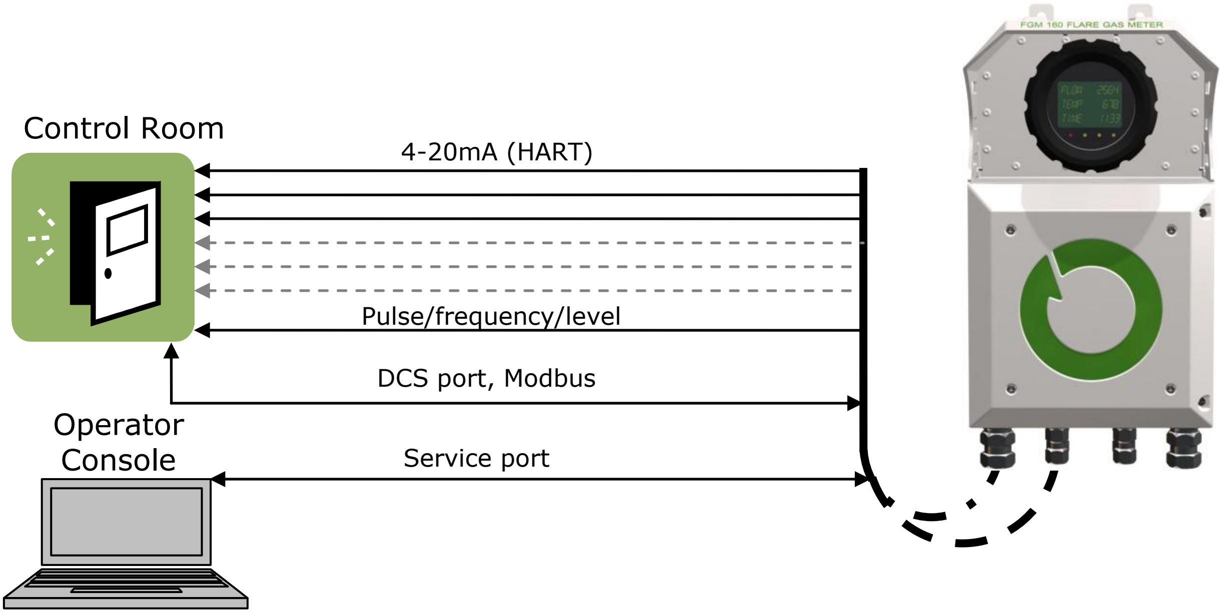


Figure 43: Data and Signal Cables.

The Service port is for the Operator & Service Console. **<u>This connection must be available in the safe area</u>** in order to enable Fluenta's support personnel to check the meter's performance, configure the meter and upload new firmware. Figure 43 shows the different connections. Operator Console and DCS wiring is normally not a part of Fluenta's scope of work.

6.2.6.1 DCS Port, Modbus

The FGM 160 can be interfaced to a DCS Modbus system by a RS 485 signal interface. Normally a 2-wire interface is used, but 4-wire interface can also be used.

For detailed information regarding the DCS port wiring, please refer to:

FGM 160 – DCS Modbus Interface Specifications, Fluenta Doc.no. 72.120.305 [4].

6.2.6.2 Service Port

The wiring of the service port is similar to the DCS port wiring.

Please refer to: FGM 160 – Operator Console Description, Fluenta Doc.no. 72.120.307 [5], for more detailed information.

6.2.6.3 Current Loop Outputs (4-20mA)

The FGM 160 has three operational 4-20mA current loop outputs as default, with additional three as an option.

Each of the current loop outputs can be configured either as active or passive output. In active output configuration, the current loop is powered from the FGM 160 field computer. In passive output configuration, an external power source is required.

In default configuration, all current loop outputs are configured as active outputs.

The current loop outputs can be configured as follows:

- Analog output.
  The output is assigned to a specific parameter/process variable and configured with a desired range.

- Alarm status output.
  The output can be configured as a specific alarm output (e.g. temperature alarm) or as a general global alarm output.
  Alarm level can be set to 4mA or 20mA.

- Level indicator output.
  The output can be configured to shift from 4mA to 20mA (or opposite) at a certain level of the assigned variable.

6.2.6.3.1 Active Output Configuration (Default Configuration)

In active output configuration the current loops are powered from FGM 160 computer (30V loop voltage).

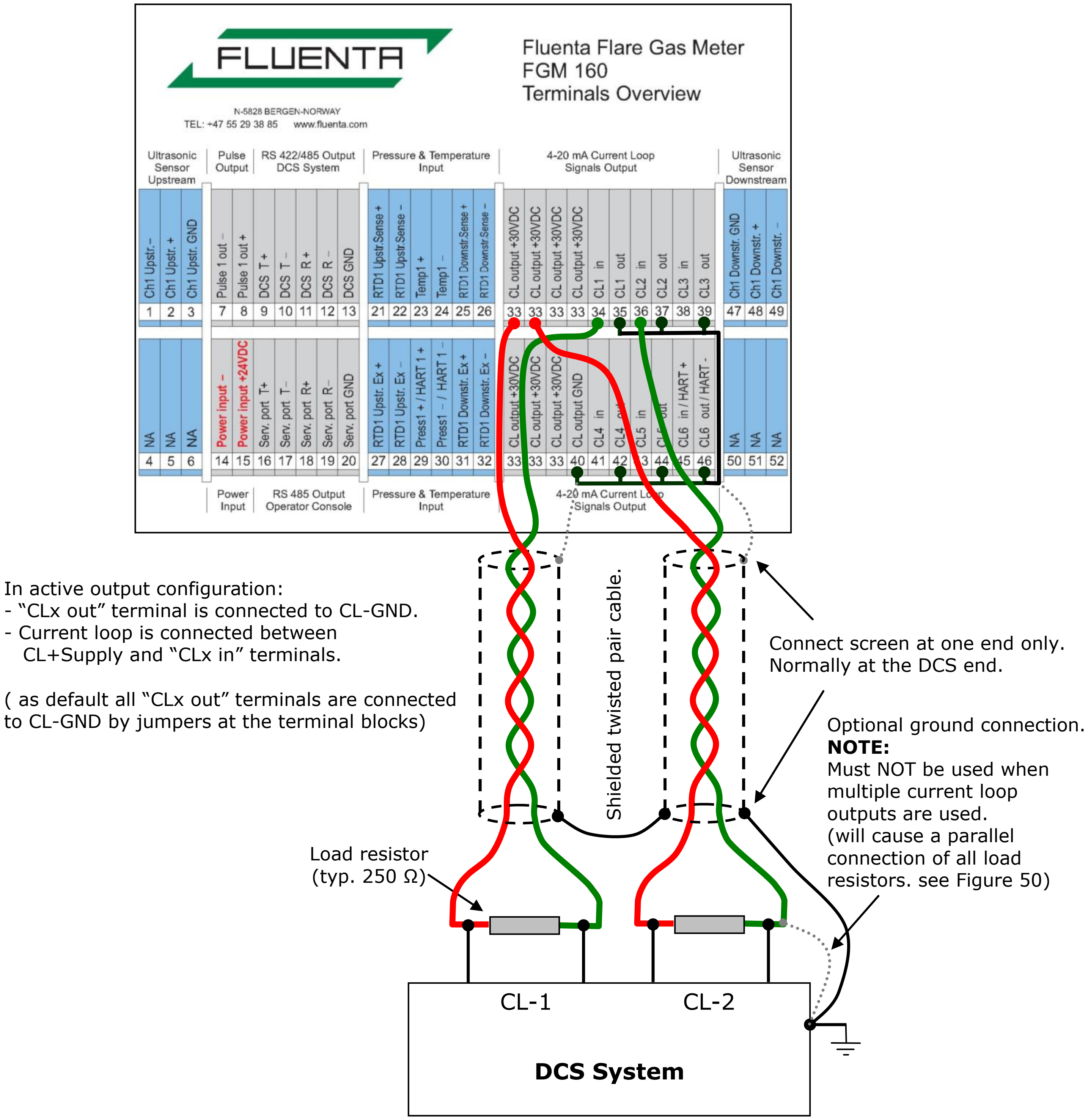


Figure 44 Active output current loop(s), wiring

6.2.6.3.2 Passive Output Configuration

In passive output configuration the current loops are powered from an external loop power source (5V – 50V, see section 6.2.6.3.4, Load / Loop Voltage Limitations, for more details).

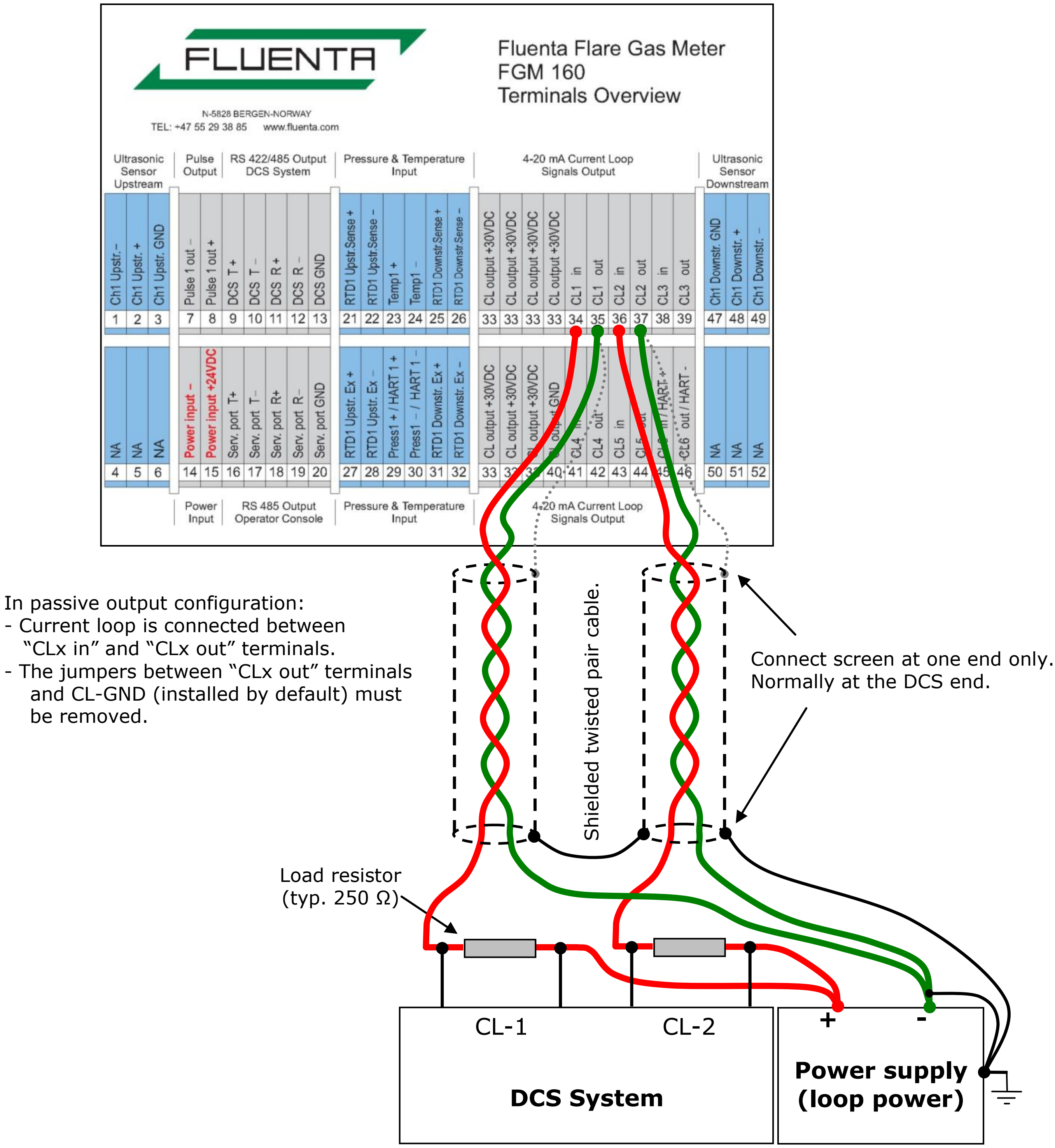


Figure 45 Passive output current loop(s), wiring

6.2.6.3.3 Current Loop Outputs Details

The current loop outputs of the FGM 160 are galvanic isolated from the rest of the FGM 160 field computer.
They are however not individually isolated with respect to each other (they all share the same ground reference point).
The outputs are protected against reverse polarity.
See Figure 46 for detailed schematic of the current loop outputs.

6.2.6.3.4 Load / Loop Voltage Limitations

A typical load resistor value is 250Ω.
This value gives a voltage on the DCS input in the range of 1 – 5V.

Active Output Configuration
In active output configuration the loop voltage is 30V.
Minimum loop resistance: 100Ω.
Maximum loop resistance: 1350Ω.

Passive Output Configuration
Minimum loop voltage: 5V.
Maximum loop voltage: 50V.
Minimum loop resistance:

- Loop voltage < 30V: R_{loop} min. = 100Ω.
- Loop voltage > 30V:
  R_{loop} min. = (Loop voltage - 28V) x 50 [Ω].

Maximum loop resistance:
R_{loop} max. = (Loop voltage - 3V) x 50 [Ω].

Table 4 Min. / max. loop resistance at typical loop voltages.

Loop voltage	R_{loop} min.	R_{loop} max.
12 V	100 Ω	450 Ω
24 V	100 Ω	1050 Ω
30 V	100 Ω	1350 Ω
36 V	400 Ω	1650 Ω
48 V	1000 Ω	2250 Ω

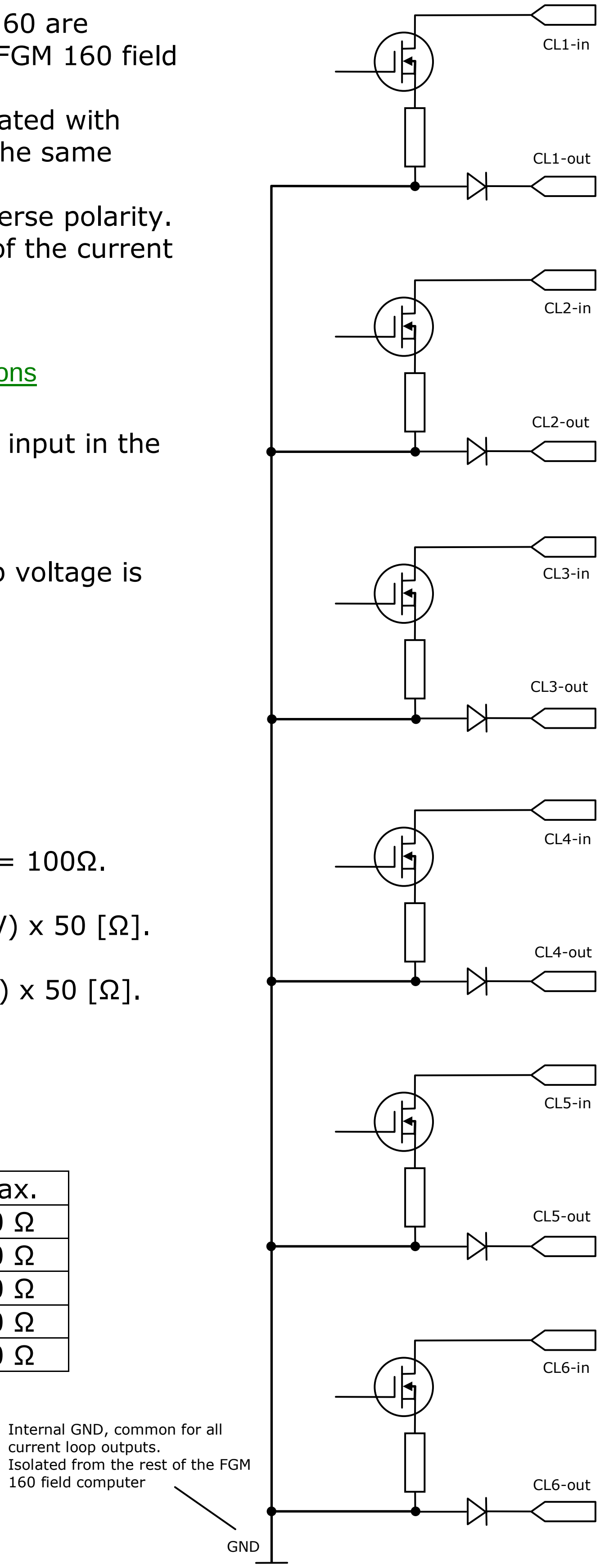


Figure 46 Current loop outputs, details

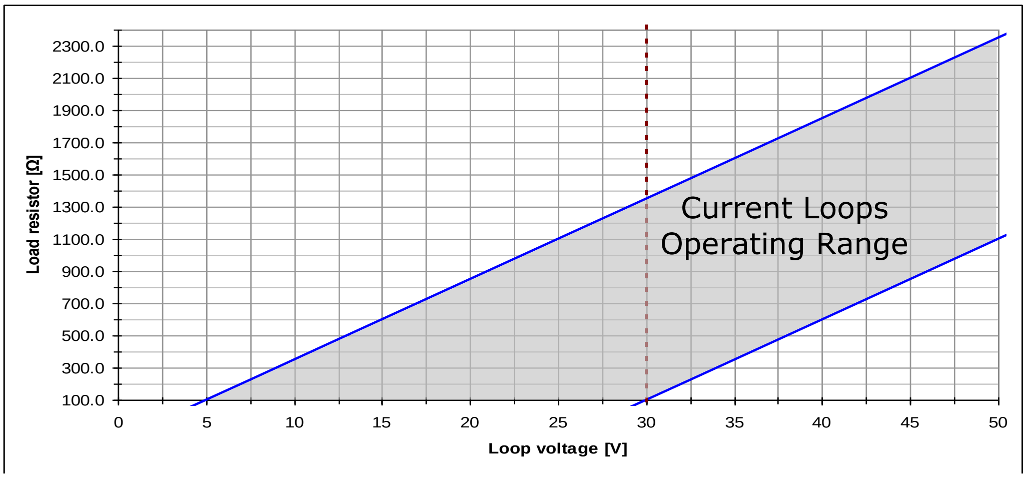


Figure 47 Current loop outputs, Load/Voltage limitations

6.2.6.3.5 Restrictions of the Current Loop Outputs

High side load / Low side load

The load resistor should normally be connected on high side (see Figure 48 and Figure 49). Low side load can alternatively be used, but only when a single current loop outputs is used/connected. If more than one current loop output is used and load resistor is connected on low side, the readings on each output will show erroneous values. The reason for this is that the current from each output will disperse over all connected outputs. (see Figure 50 and Figure 51)

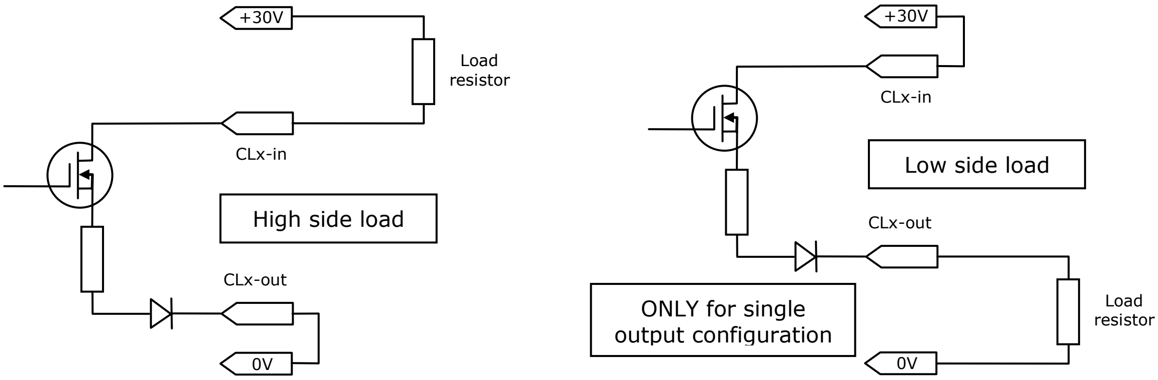


Figure 48 Current loop active output, High side load and Low side load

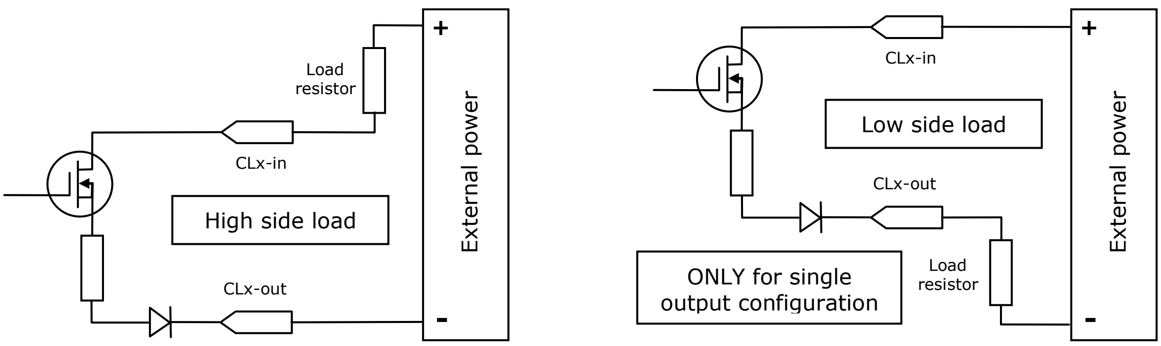


Figure 49 Current loop passive output, High side load and Low side load

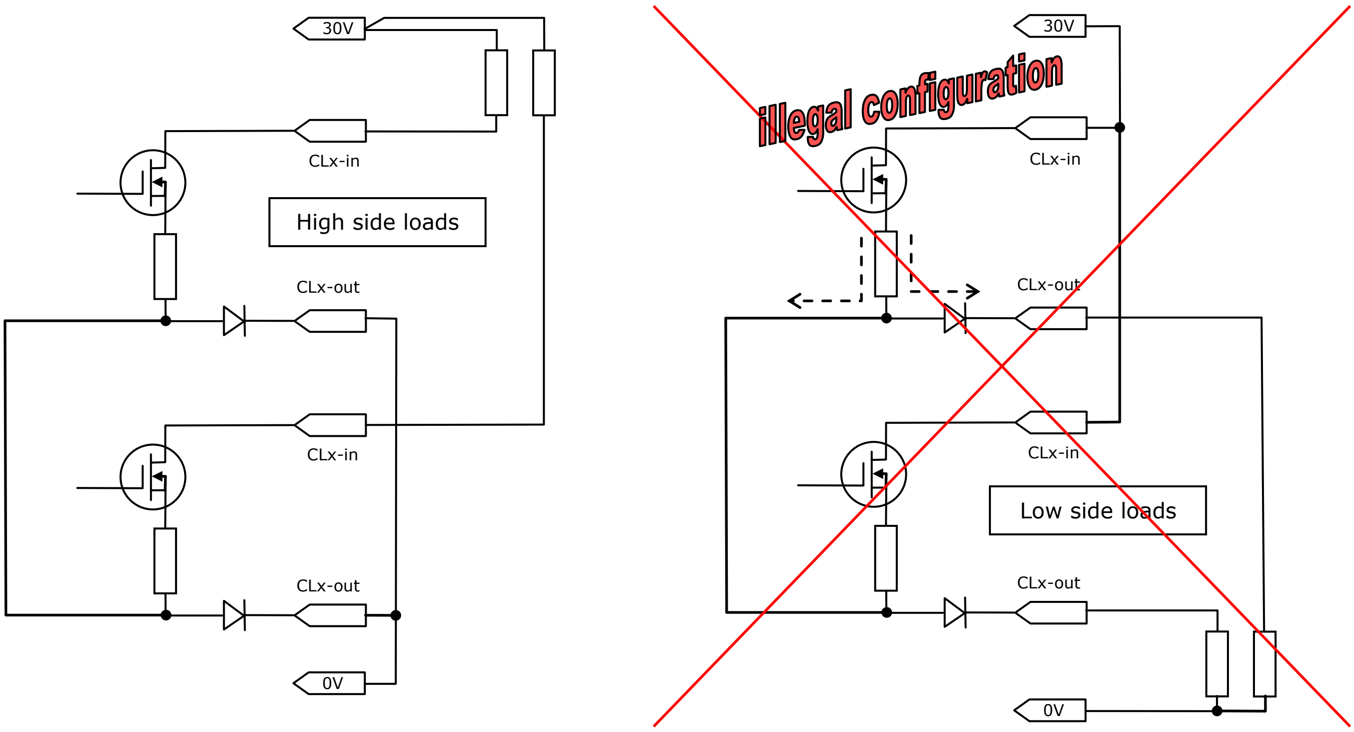


Figure 50 Multiple current loop outputs, Active output configuration

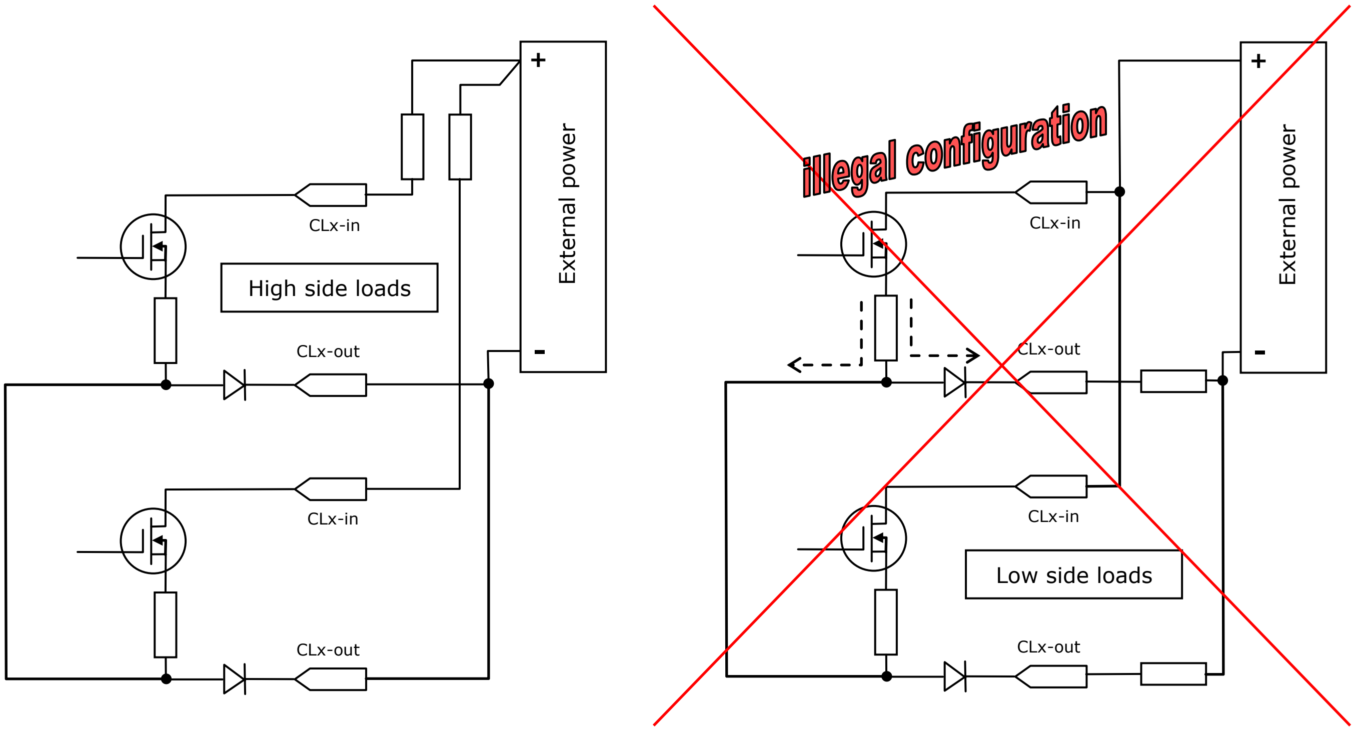


Figure 51 Multiple current loop outputs, Passive output configuration

6.2.6.4 HART Output

One of the current loop outputs (CL6) can be configured and used as a HART communication channel.
For detailed information regarding wiring of the HART output channel, please refer to: FGM 160 – HART Output Interface Specification, Fluenta Doc.no. 72.120.306 [6].

6.2.6.5 Pulse/Frequency/Level Output

As an option, the FGM 160 can be configured with one passive pulse/frequency/level output.
This output can be configured in three different ways:

- Pulse output configuration.
  The pulse signal can be used e.g. to interface an external totalizer/counter.
- Frequency output configuration.
  The frequency signal can be used as an alternative to analog current loop output.
- Level output configuration.
  This signal can e.g. be used for alarm or status output.

6.2.6.5.1 Voltage / Current Limitations

Maximum voltage: 30V
Maximum current: 40 mA (output is protected by a 62mA internal fuse)

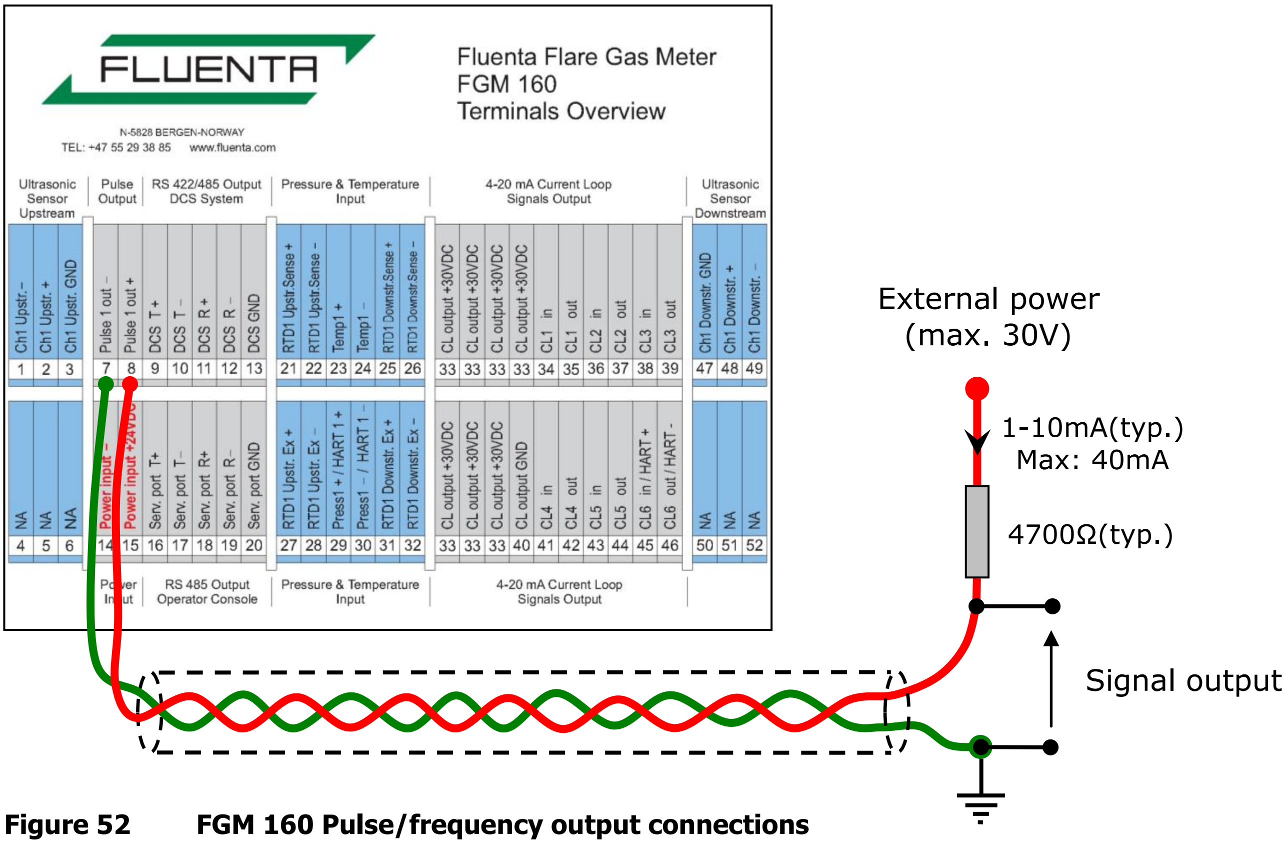


Figure 52 FGM 160 Pulse/frequency output connections

6.3 Upgrading from the FGM 130

It is relatively simple to upgrade an existing FGM 130 installation to the FGM 160. Existing mounts can be used, although the transducers must be replaced, as the FGM 160 uses upgraded Ultrasonic Transducers, and the signal is not backward compatible with the Ultrasonic Transducers used with the FGM 130. The existing temperature and pressure sensors can be used, and the fiber optic cables can be re-used for DCS signal transmission with the addition of an RS485 optical converter. The figure below shows the similarities and differences between the FGM 130 and FGM 160 setups.

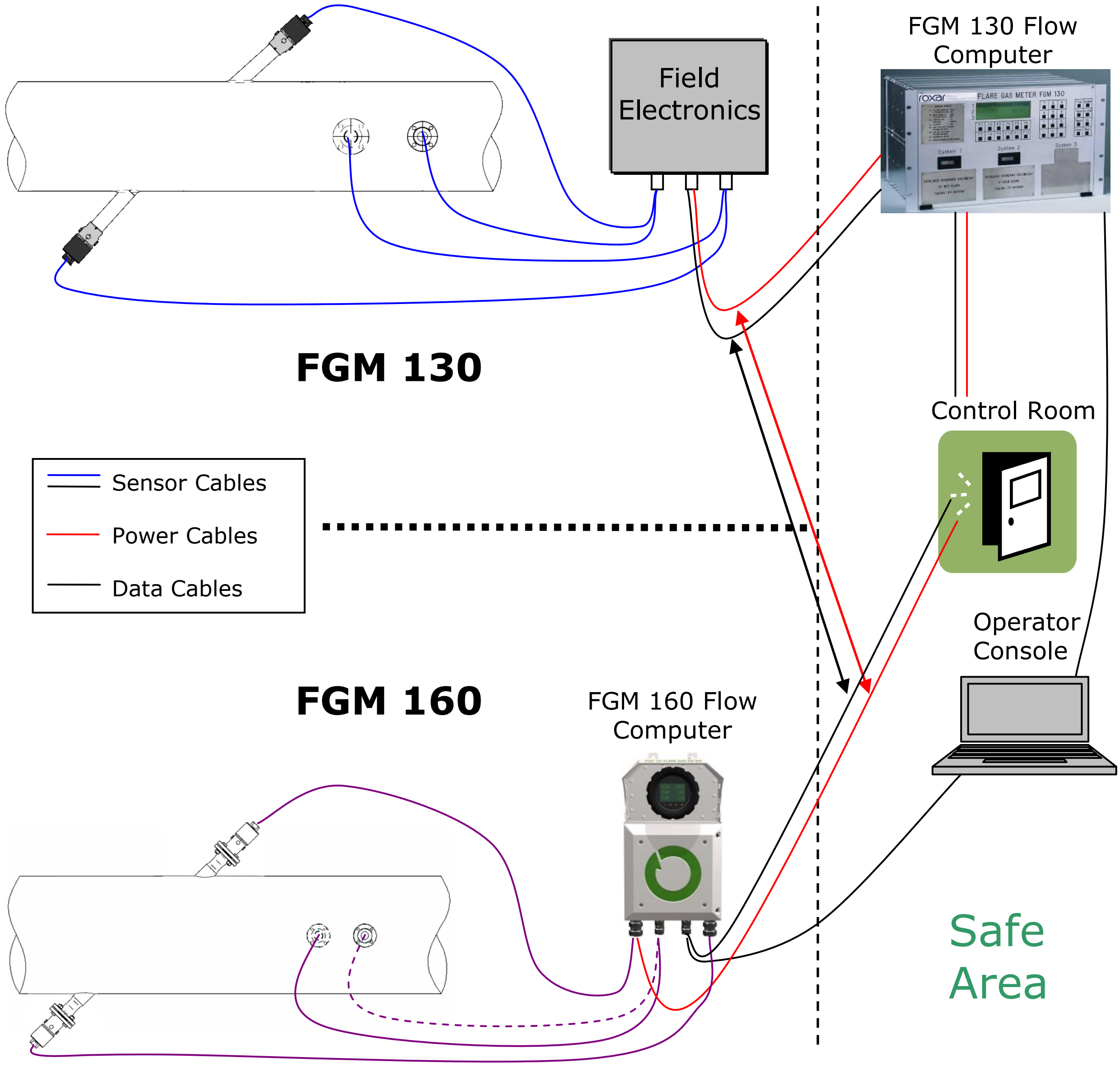


Figure 53 FGM 130 –> FGM 160 upgrade

The table below shows the components of the FGM 130 that can be re-used when upgrading to the FGM 160.

FGM 130		FGM 160
Flow Computer	No	Replaced by FGM 160 Computer
Field Electronics Enclosure	No	Integrated in FGM 160 Computer
Ultrasonic Sensors	No	New FGM 160 sensors
Pressure Transmitter	Yes	Interface directly to FGM 160 Computer
Temperature Transmitter	Yes	Interface directly to FGM 160 Computer
Power Cable	Yes	Power or Communication
Fiber Optic Signal Cable	Yes	Communication (RS422/RS485)
Sensor Holders	Yes	
DCS/SCADA Interface	Yes	Compatible, with an additional HART interface

7. References

[1] FGM 160 Preservation, Packing, Unpacking and Storage Procedure, Fluenta Doc.no.: 62.120.002

[2] FGM 160 – Hazardous Area Installation Guidelines, Fluenta Doc.no. 62.120.006

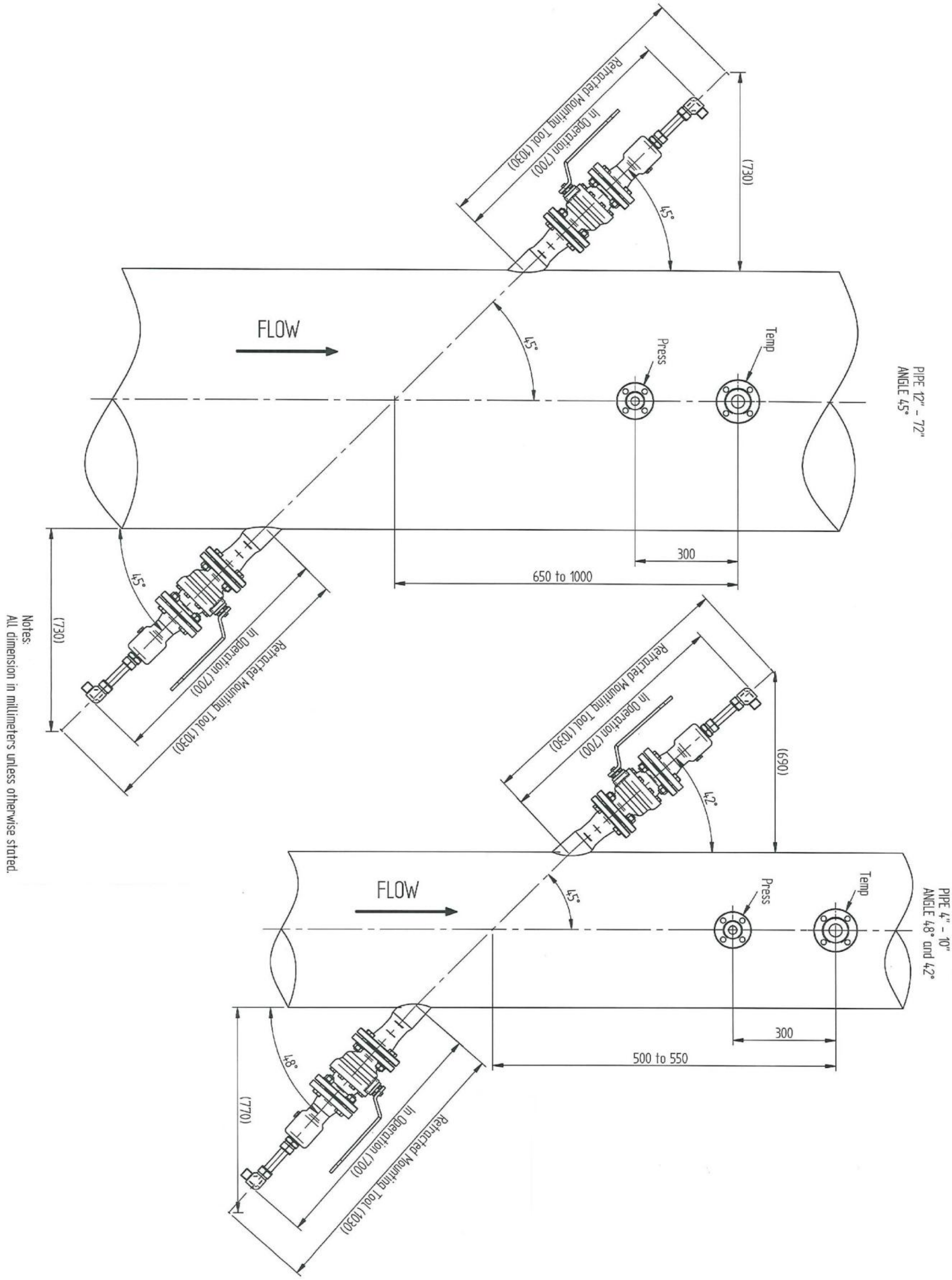
[3] FGM 160 - Field Wiring Diagram, Fluenta Doc.no.: 77.120.504

[4] FGM 160 – DCS Modbus Interface Specifications, Fluenta Doc.no. 72.120.305

[5] FGM 160 – Operator Console Description, Fluenta Doc.no. 72.120.307

[6] FGM 160 – HART Output Interface Specification, Fluenta Doc.no. 72.120.306

8.Space Requirements for the TFS



5.3 Hazardous Area Installation Guidelines

1. Purpose

This document provides installation guidelines for the FGM 160 Flare Gas Meter in order to ensure safe use of the system in a potential explosive atmosphere.

2. Abbreviation/Definitions

2.1 Abbreviations

FGM 160	Fluenta Flare Gas meter, Model FGM 160
TFS	Transducer Full Size

2.2 Definitions

Ex-d/e	-	Equipment in Ex-d explosion proof enclosure and connection housing in Ex-e enclosure.

3. General

This document is not a complete installation and hook-up instruction for the FGM 160. For complete installation instructions, please refer to Fluenta doc. 62.120.001 – Installation and Hook-Up Instructions.

4. Unpacking

4.1 Inspection of Goods

Installation of the equipment supplied by Fluenta must never occur without the inspection of the supplied goods carried out first. This should be performed according to relevant quality assessment schedules.

5. Ex-Certificaton and Marking

5.1 Ex-Classification Marking

Make sure that the FGM 160 is certified for the area and hazardous zone it is intended to be installed in. The system marking is shown in Figure 54. This marking states which areas the Ex-d or Ex-d/e Field Computer and the ultrasonic transducers are certified for, according to ATEX Directive 94/9/EC requirements. The ATEX label is fixed to the right hand side of the FGM 160 Field Computer. Other Ex-marking may be applied according to the area of installation, e.g. CSA, GOST etc.

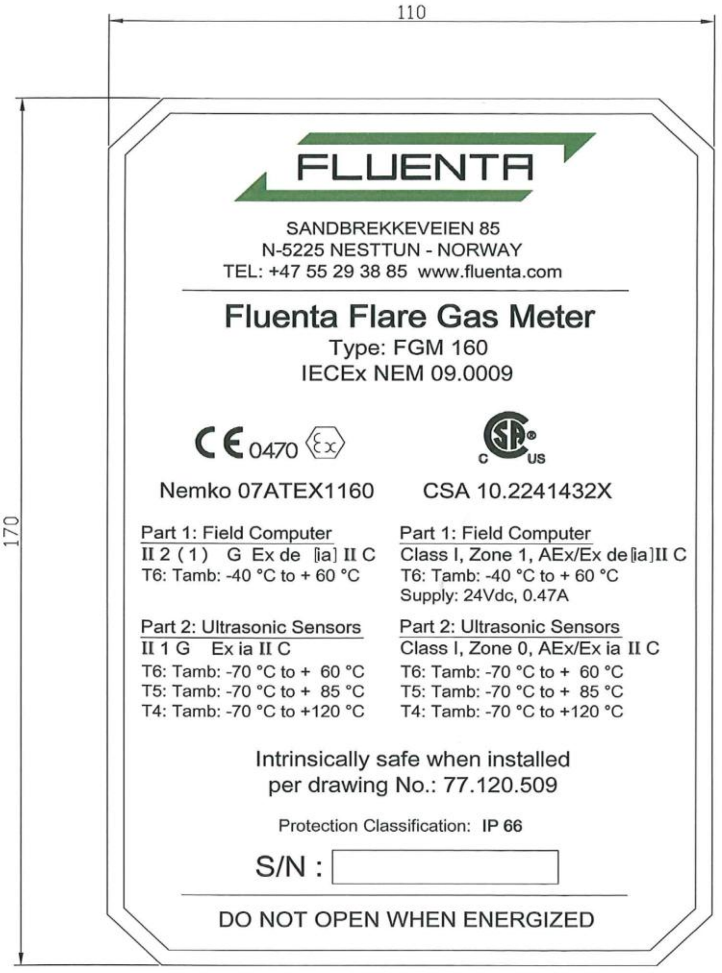


Figure 54 ATEX and CSA marking of the Fluenta Flare Gas Meter, FGM 160. Other Ex-marking may be applied according to certification requirements for the specific area of equipment installation.

5.2 FGM Sensor Marking

The FGM ultrasonic transducers are marked with a tag identifying the sensor serial number and the Ex-classification, ref. Figure 55.

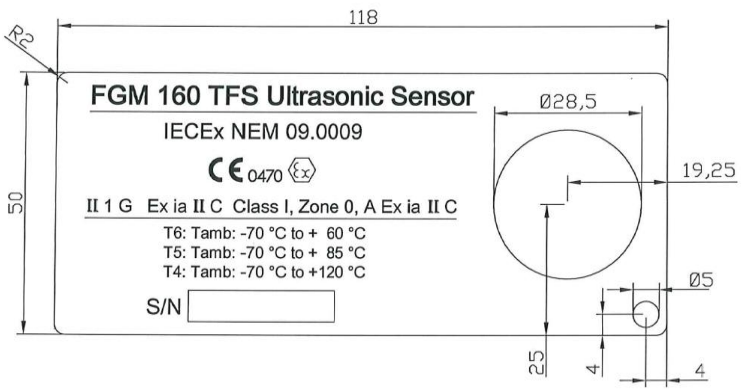


Figure 55 FGM 160 Sensor Label Plate.

5.3 Equipment Information

The following ratings apply for the FGM 160 Flare Gas Meter:

Electrical rating (input power)	+24 VDC nom. (20 – 32 VDC) *)
Maximum power consumption	13 W
Input power fuse rating	1.25 A
Ingress Protection, Ex-d/e Version;	
Ex-d enclosure	IP 66
Ex-e enclosure	IP 66
Enclosure information;	
Ex-d: Technor TNXCD 130	DNV-2003-OSL-ATEX-0436U
Ex-e: Technor TNCN 284615	DNV-2001-OSL-ATEX-0176
Bushing: Technor TNDLD	Nemko-01-ATEX-471U

*): The FGM 160 requires +24 VDC input. If +24 VDC is not available, an optional 110-230 VAC/24 VDC converter can be supplied by Fluenta, mounted in an Ex-d explosion proof enclosure.

Note!

The FGM 160 Field Computer is not equipped with an ON/OFF switch. Thus, it should be assumed that power is present unless it is made absolutely sure that no power is present at the terminals.

5.4 Pressure and Temperature Transmitter Interface Specifications

The FGM 160 can interface to Ex-i/Ex-d classified Pressure and Temperature transmitters with 4-20 mA/HART interface, through their dedicated IS-terminals only. Ref. terminal block connections inside the FGM 160 Field Computer Ex-e enclosure.

Io = 0.09A Ro= 304 ohm Co=0.088yF Lo/Ro=58uH/ohm	Uo = 27.3V Po= 0.62W Lo = 3.5mH

Figure 56 Specifications for 4-20 mA/HART inputs from Pressure and Temperature transmitter connections.

5.5 Manufacturer Information

The FGM 160 Flare Gas Meter is manufactured by Fluenta AS:

Visiting address:
Sandbrekkeveien 85
Nesttun, Bergen
Norway

Telephone/Fax:
Telephone: +47 55 29 38 85
Fax: +47 55 13 21 60

Mail address:
P. O. Box 115, Midtun
N-5828 Bergen
Norway

E-mail addresses:
Sales: sales@fluenta.com
Support: support@fluenta.com

6. References

62.120.001 – FGM 160 Installation & Hook-Up Instructions.

7. APPENDIX 1

Connection of Ex Pressure and Temperature transmitters is outlined in Figure 57. Requirements for transmitters that do and do not comply with IEC 60079-11 Ed. 5, Clause 6.3.12 is listed below, as well as requirements for transmitters with Ex-d protection.

Requirements for transmitters which comply with IEC 60079-11 Ed. 5, Clause 6.3.12 (Dielectric strength test): **Intrinsic safe parameters for each transmitter:** **Ui = 27.4V (minimum) Ii = 91mA(minimum) Pi = 0.63W(minimum)**	**Requirements for transmitters which do not comply with IEC 60079-11 Ed. 5, Clause 6.3.12 (Dielectric strength test)** **Intrinsic safe parameters for each transmitter:** **Ui = 27.4V (minimum) Ii = 91mA(minimum) Pi = 0.63W(minimum)** **Special conditions for safe use:** **Grounding cable with minimum 4mm2 cross section connected from transmitter housing to protective earth.**
Requirements for transmitters with Ex d protection: **No special requirements**	

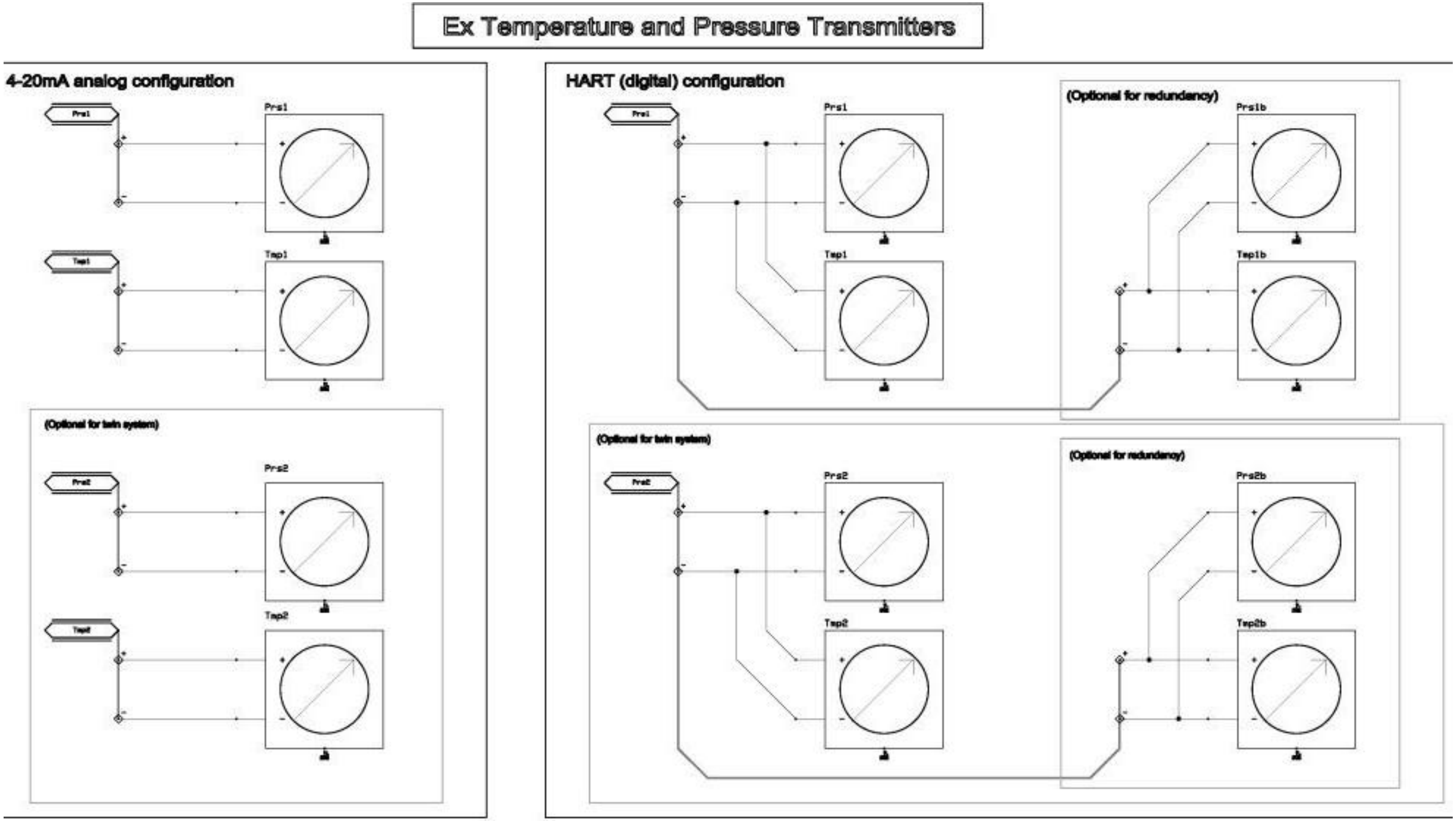


Figure 57 Ex Pressure and Temperature transmitter connections.

6. OPERATING INSTRUCTIONS

6.1 Operating Instructions
6.2 DCS Modbus Interface Specifications
6.3 HART Outputs Interface Specifications
6.4 Operator Console Description

6.1 Operating Instructions

1. Purpose

This document describes the Fluenta Flare Gas Meter, FGM 160 hardware and software, and the device integrity.

2. Abbreviations/Definitions

2.1 Abbreviations:

TFS	Transducer Full Size
DCS	Distributed Control System
O&S C	Operator & Service Console

2.2 Definitions:

Operator & Service Console	- PC software with graphical interface for configuring and monitoring the FGM 160 Field Computer

3. General Information

3.1 Hardware Description

The FGM 160 Field Computer, illustrated in Figure 58, is designed as a distributed system. The FGM 160 consists of five or six modules, the Digital Signal Processing (DSP) module, the Analogue Front End (AFE) module, the Pressure & Temperature (P&T) module, Input/Output (I/O) module, Intrinsic Safe Barrier (IS Barrier) module, Surge Protection module and the Local Display. A distributed system gives several advantages. This design will be more flexible with respect to future expansions and modifications, as the total processing load for the system can be divided on several modules. Thus, the danger of overloading a single CPU unit is reduced.

Figure 58 – FGM 160 Field Computer.

The FGM 160 is certified for operation in Hazardous Area.

For detailed information regarding Hazardous Area installation and operation, please refer to Fluenta Doc. no. 62.120.006 (FGM 160 – Hazardous Area Installation Guidelines) and Fluenta Doc. no. 75.120.200 (FGM 160 Hazardous Area Certificates).

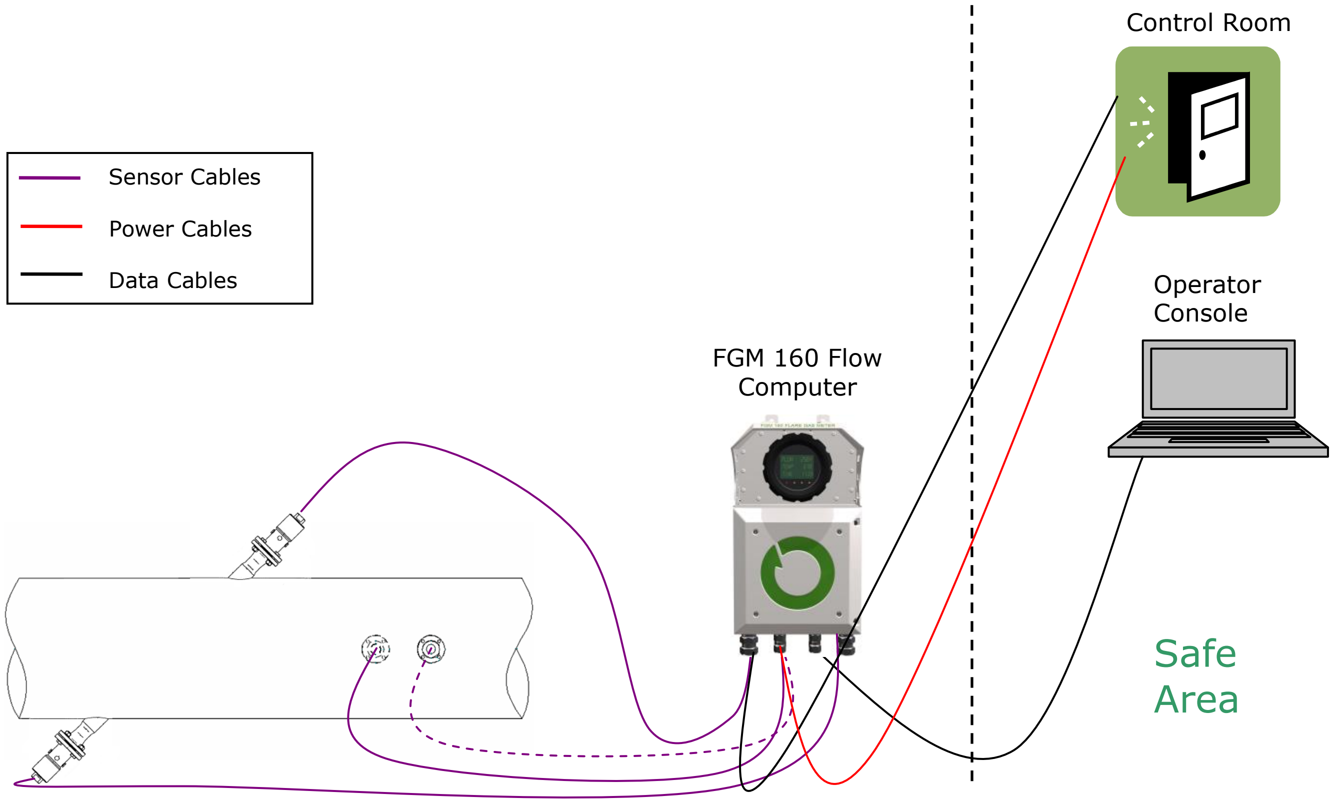


Figure 59 – FGM 160 Hook-Up, with the Field Computer, Ultrasonic Transducers, Pressure and Temperature Transmitters, and connections to Safe Area equipment.

3.1.1.1 Electrical Connections

Please refer to Fluenta Doc. no. 62.120.001 (FGM 160 Installation & Hook-Up Instructions) for detailed information regarding all electrical connections.

3.1.1.2 Power Supply

The FGM 160 requires 24 VDC power supply (nominal). If 24 VDC is not available, an optional 110-230 VAC/24 VDC converter can be supplied by Fluenta.

For detailed equipment information and equipment ratings, please refer to Fluenta Doc. no. 62.120.006 (FGM 160 - Hazardous Area Installation Guidelines).

3.1.1.3 Input Signals

3.1.1.3.1 Ultrasonic Transducers

FGM 160 ultrasonic transducers are connected to the FGM 160 Field Computer by means of the included prefabricated signal cables.

3.1.1.3.2 Pressure and Temperature Transmitters

The FGM 160 can be configured to accept analog 4-20 mA transmitters or HART compatible transmitters. The pressure and temperature transmitters may be omitted if the system is configured to get the pressure and temperature data from the DCS system (Modbus communication link).

3.1.1.4 Output Signals

3.1.1.4.1 Modbus Communication (RS-485)

The FGM 160 has two separate Modbus communication ports.

One is dedicated for communication with a DCS system. The second is a service port for configuration and monitoring of the FGM 160 system.

3.1.1.4.2 Current Loop Outputs

Up to 6 current loop outputs are available for output of selectable parameter values, where 3 analog output is configured as default. The 4-20 mA current loop output channels can be configured as active or passive outputs.

3.1.1.4.3 HART Output

One of the current loop outputs can also be configured for HART output communication. Ref. Fluenta Doc. no. 72.120.306 (FGM 160 – HART Output Interface Specification) for details.

3.1.1.4.4 Pulse/Frequency Output

The FGM 160 can also be configured to provide a pulse or frequency output signal. The pulse output will represent a totalised increment (of e.g. volume or mass), whereas the frequency output will represent a process parameter (e.g. volume flowrate, mass flowrate etc.)

3.1.2 Electronic Modules in FGM 160

3.1.2.1 Digital Signal Processing (DSP) Module

The Digital Signal Processing module is, as its name indicates, the processing module in the system. The DSP Module generates the ultrasound measurement signals and controls the measurement sequences. It collects data from the other module registers and performs flow calculations based on these data. All calculated parameters are stored in defined registers. All of these registers are available for the Operator & Service Console through the Modbus service port at the I/O Module. A selection of these registers is also available for the DCS system (through the DCS port at the I/O Module).

3.1.2.2 Analogue Front End (AFE) Module

The Analogue Front End Module is the interface between the DSP Module and the ultrasonic transducers via the IS-Barrier unit. At the AFE Module, measurement signals are multiplexed and switched between upstream and downstream direction.

3.1.2.3 Pressure & Temperature (P&T) Module

The Pressure & Temperature Module collects pressure and temperature information from external sensors via 4-20 mA current loop or HART Interface. All pressure and temperature data are stored in predefined registers available for the DSP Module. Thus, the DSP unit can retrieve P&T parameters in a minimum of time.

3.1.2.4 Input/Output (I/O) Module

The Input/Output Module is the interface between the FGM 160 in hazardous area and equipment in safe area. At the I/O Module, 24 VDC (nom.) supply voltage is converted to the required operational voltages for the other modules. Further, all signals and communication to and from the DCS system and Operator & Service Console are handled by this unit.

3.1.2.5 Intrinsic Safety Barrier (IS Barrier) Module

The Intrinsic Safety Barrier Module ensures the intrinsic safety for operation of the ultrasonic sensors mounted in hazardous area In addition, the IS-Barrier Module includes safety barriers for the P&T transmitters. Thus, P&T transmitters with "Ex i" certification can be interfaced directly to the FGM 160. For specifications regarding the P&T transmitter barriers, please refer to Fluenta Doc. no. 62.120.006 (FGM 160 – Hazardous Area Installation Guidelines).

3.1.2.6 Surge Protection Module

The Surge protection Module protects the power input and the signal output lines from externally generated spikes, surges and overvoltage.

3.1.2.7 Local Display Module

The Local Display (LD) Module is the front unit, visible through the Ex-d safety glass. At the LD, a set of predefined metering process parameters can be viewed. Further, four LEDs give the status of Power, Alarms, Measurement and Communication.

3.1.3 Non Resettable Counter Function

The non-resettable counter function will record and keep the totalized volume and mass. The totalized values are accessible through the DCS Modbus interface or through the Operator & Service Console.

3.2 Firmware Description

In the following sections, a general description of the firmware for the different modules is outlined.

3.2.1 DSP Module

- The DSP Module initializes the system at start-up. Tasks are set to initial states and the system is ready for operation.
- The signals transmitted by the ultrasound transducers are generated by the DSP Module. The sequencing is controlled by this module, and depending on the velocity of the medium in the pipe, either both Chirp and CW signals or just Chirp signals are used for the flow measurements. One ultrasonic transit time measurement is always succeeded by an ultrasonic transit time measurement in the opposite direction.
- Data sampling and signal processing are carried out after a specified number of sequences. The DSP module then calculates the difference in transit time measurements and calculates the parameters available in the FGM system.
- Flow velocity and volume flow rate calculations run continuously, calculating new values based on data from the P&T module and transit time measurements from the ultrasonic transducers.
- Gas density and mass flow calculations are calculated based on calculated velocity of sound and measured pressure and temperature.
- Volume and mass totalising calculations are continuously updated based on volumetric and mass flow rate calculations.
- All system configuration parameters are stored in the Flash memory (non-volatile memory) at the DSP Module.
- The DSP Module carries out self checking and evaluation of input and calculated parameters.

3.2.2 P&T Module

- The P&T Module continuously collects pressure and temperature values from the external pressure and temperature transmitters mounted downstream of the FGM 160. These readings are used in calculations performed by the DSP module.
- In addition to the external temperature reading, the P&T also reads the internal temperature value. This value is used to monitor the internal temperature in the Ex-d enclosure.

3.2.3 I/O Module

- The I/O Module handles all signals and communication with systems in Safe Area.
- Data requests and commands from Operator Console are processed by the I/O Module. A predefined number of accessible parameters are available from the FGM. Accessible parameters depends on whether 4-20 mA, HART or Modbus is utilized.
- Software downloads to the DSP-, P&T- and I/O Module are carried out by the I/O-module.
- All data requests from DCS system are handled by the I/O Module; either through Modbus or HART interfaces.

3.3 Device Integrity

3.3.1 Self Checking

The FGM 160 performs a self-checking sequence, where it checks that inputs from the transducers and Temperature and Pressure transmitters are within valid range, and that other functions are operating as intended.

3.3.2 Watchdog Timer

The Watchdog Timer is initialized at start-up, and can not be disabled, ensuring that if the unlikely situation of system hang-up should occur, the Watchdog Timer will reset the system forcing a complete reboot and start-up.

3.3.3 Flash Memory

System configuration is stored in Flash Memory (non-volatile memory). In case of a power break, all system configurations are reloaded from the Flash memory

3.4 Configuration and Operating Software

Through the FGM 160 Operating & Service Console (O&S C), the operator can monitor process data, configure the meter and specify process data to be saved to a data log file for later analysis. The O&S C further enables the operator to operate the meter remotely, by using e.g. a RS 485 / TCP/IP converter and remote control software.

It should be noted, though, that the O&S C is not required in order for the FGM 160 to operate as intended. The meter is shipped with configuration according to project-specific Instrument Data Sheet (IDS). If IDS was not available at delivery standard configuration is put and customer-specific settings are done while commissioning.

4. Operating Procedure

4.1 Introduction

This section provides information about how to operate the FGM 160 field computer. The FGM 160 is a field mounted stand-alone ultrasonic gas flow measurement system, and does not require any safe area communication device in order to operate. However, in order to continuously monitoring data and the meter performance, it is recommended to use the Operator & Service Console (O&S C). This program will provide hands-on process and status data continuously, with possible remote access to the FGM 160 system from any remote system with the appropriate remote control software installed.

4.2 Power-Up Sequence

The power-up sequence describes the necessary handling of the FGM 160 in order to ensure correct operation.

1. Connect all power, input and output signals and communication cables according to the project specification and all relevant procedures and instructions.

2. Make sure that the power cable is connected to a suitable power source, either directly to a 24 VDC supply or through a 110-240 VAC / 24 VDC converter.

3. Turn on the power to the FGM 160. There is no power switch on the FGM 160 Field Computer, so the power must be turned **ON** and **OFF** by an external switch or similar, preferably in safe area.

4. At startup, the FGM 160 will go through a boot and an initialization sequence before entering the standard operational (measurement) mode.

5. When the FGM 160 has entered the standard operational (measurement) mode, the meter will, according to the system configuration, carry out transit time measurements, retrieve pressure and temperature data, calculate volumetric and mass flow rates and either actively output a set of predefined parameters at the analog 4-20mA outputs, or make a set of process parameters available for DCS HART or Modbus communication.

4.3 Field Computer Configuration

The FGM 160 can be configured by using the Operator & Service Console. During manufacturing, the project specific configuration is entered into the Field Computer. The system configuration can be modified at any time by using the Operator & Service Console (O&S C). All system configuration parameters are stored in non-volatile memory, ensuring that no configuration parameters are lost in case of power loss.

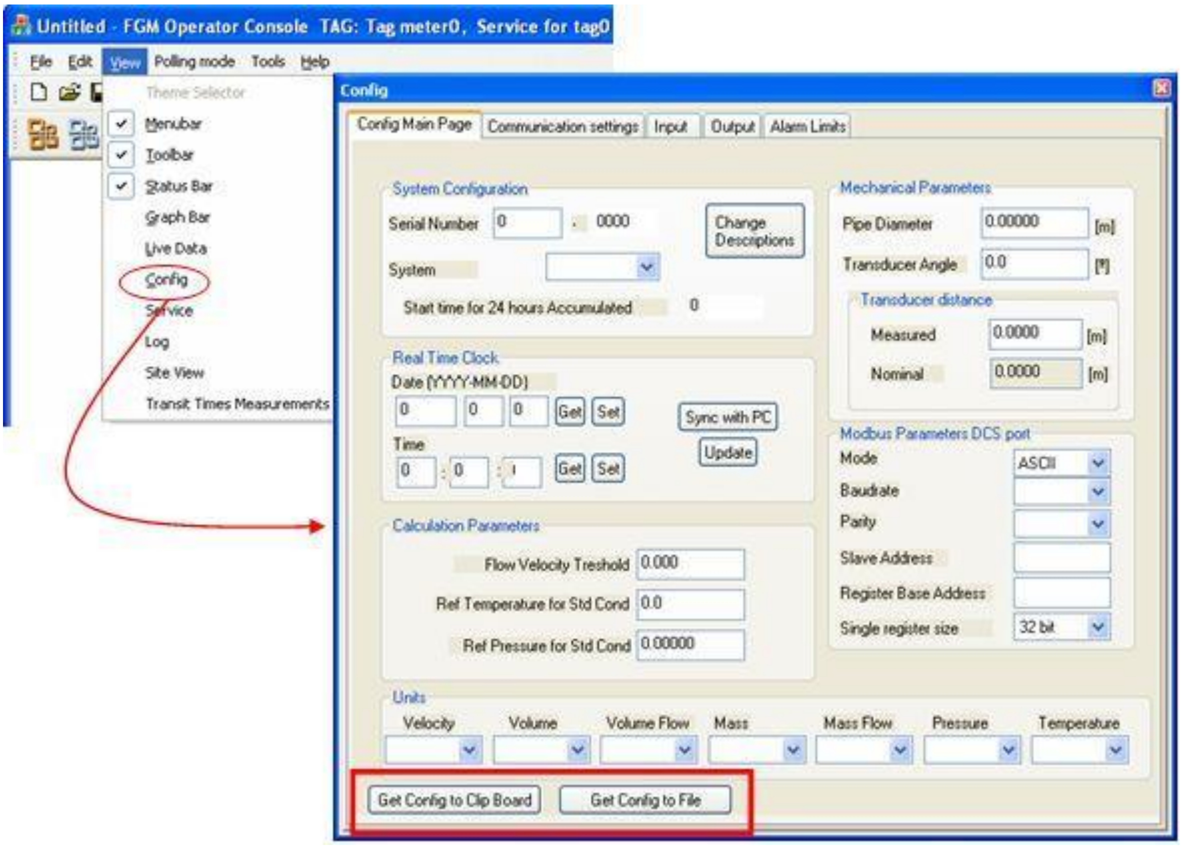


Figure 60 Download of system configuration using the Operator & Service Console.

The system configuration parameter file can be downloaded from the FGM 160 using the Operator & Service Console, ref. Figure 60, by entering the "Config Main Page" through the "View – Config" menu bar. The system configuration can either be copied to the clipboard and pasted into a document, or saved directly to a file.

For a full listing of a system configuration file, refer to Appendix I.

Some of the system configuration parameters are also available through the DCS Modbus registers. However, parameters that should only be accessed by authorized personnel are not accessible through this communication line. For a full listing of accessible configuration parameters through the DCS Modbus interface, refer to Fluenta Doc.no. 72.120.305 – FGM 160 DCS Modbus Interface Specifications.

4.4 Local Display Functions

The FGM 160 is equipped with a local LCD display mounted at the front, and visible through the Ex-d safety glass. The display shows predefined process parameters from the FGM 160. Further, 4 status LEDs are visible at the front for the following status information:

- **Power**
  This LED will have a green light when the system power is ON.

- **Status**
  This LED will light:
  GREEN; if no Alarms are active (system status OK).

- **Comm**
  This LED will light:
  GREEN; during Modbus frame reception or sending.

- **Meas**
  This LED will blink GREEN at a regular cycle, indicating that ultrasonic measurement cycle sequence is active.

4.5 Error Check and Troubleshooting

The operator should not perform extensive troubleshooting beyond what is described in this section. For repair and module replacement, contact Fluenta AS.

Fluenta AS
Sandbrekkeveien 85
P.O. Box 115, Midtun
N-5828 Bergen
NORWAY

Phone: +47 55 29 38 85
E-mail: support@Fluenta.com

Error check can be carried out by using the Operator & Service Console

NOTE!

Before any work can be carried out with the FGM 160 field computer, a hot work permit must be obtained.

Do not connect or disconnect any signal wires unless the power is turned OFF!

Do not open the Ex-d enclosure containing the field electronics in hazardous area, without first making sure that the conditions approve such action. Preferably, and as a general rule; the Ex-d enclosure should only be opened indoors in e.g. a workshop in safe area.

4.5.1 Error Check with Local Display

As described in Section 4.4, 4 LEDs are visible at the front with status information. If one or more of these LEDs do not have a GREEN light color indicating OK status, the following status is present and actions should be taken:

- **Power**
  Indication: The LED is not ON (no green light).
  Status: System Power is OFF, or LED does not work.
  Action: Check that the system Power wires are connected and that 24 VDC is present at the power input terminals.

- **Meas**
  Indication: The LED is steady OFF or steady GREEN.
  Status: The FGM 160 is not in standard operational (measurement) mode.
  Action: Check the Alarm log for any error messages indicating any cause for the problem. Turn the system Power OFF and ON again. If the situation remains unchanged, contact Fluenta AS for guidance.

4.5.2 Error Check with O&S C

Through the FGM 160 Operator & Service Console, data can be logged for trend analysis and evaluation. Data can be logged to a data file and imported in e.g. Excel spreadsheet for plot and analysis.

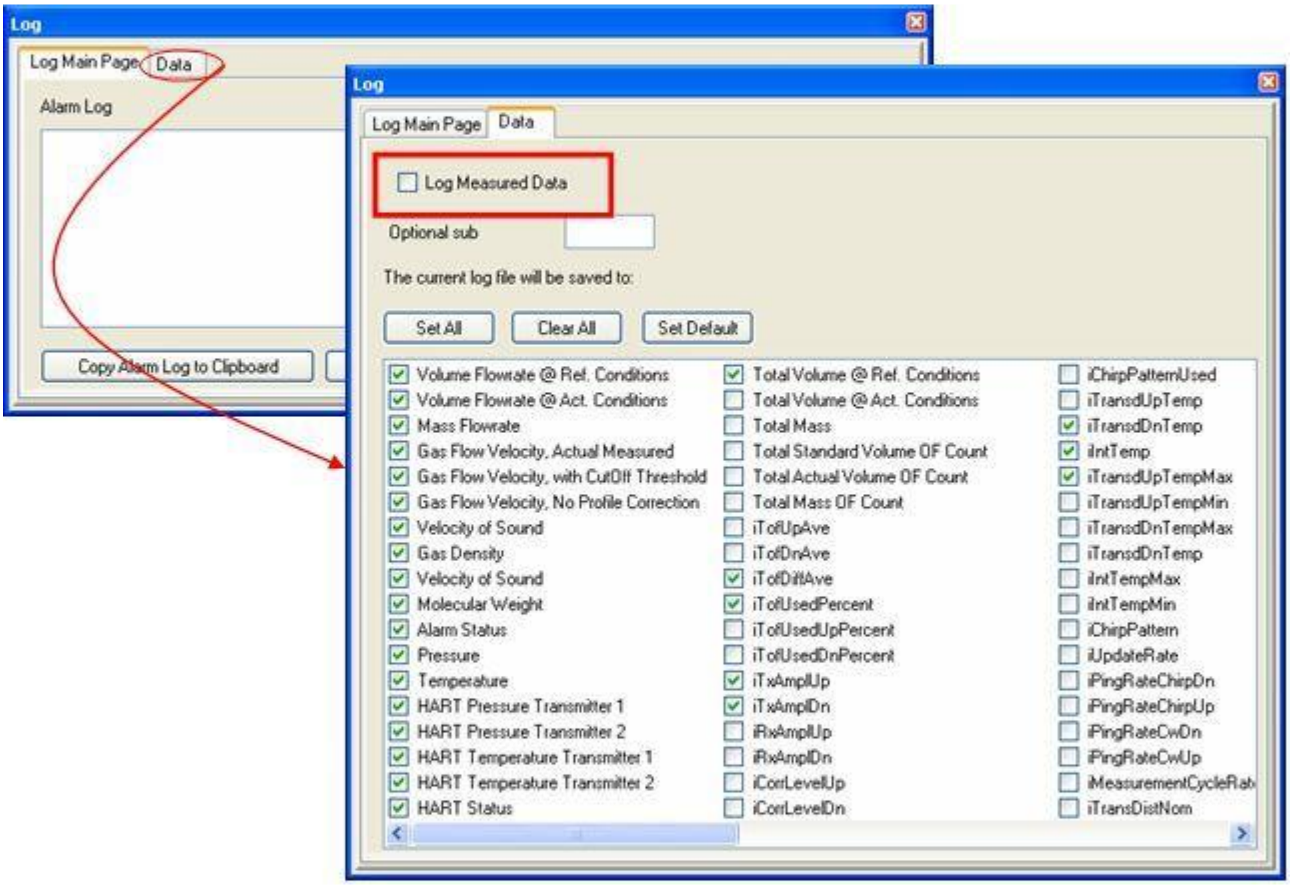


Figure 61 **Activating the "Log Measurement Data" function at the "Log Data" window most parameters can be logged to a data file. The data log file name will be generated automatically based on the current date and time.**

By using the Operator & Service Console, it is also possible to carry out remote diagnostics. Thus, a Fluenta AS service engineer, being granted access to a specific system by the end operator, can monitor the performance of the meter and carry out analysis based on logged and live data. This function requires internet connection, and communication wires to service port.

5. References

[1] FGM 160 – Hazardous Area Installation Guidelines, Fluenta Doc.no. 62.120.006

[2] FGM 160 Hazardous Area Certificates, Fluenta Doc.no. 75.120.200

[3] FGM 160 Installation & Hook-Up Instructions, Fluenta Doc.no. 62.120.001

[4] FGM 160 DCS Modbus Interface Specifications, Fluenta Doc.no. 72.120.305

6. Appendix I – System Configuration File

```
***************************************************
***************************************************
*****************                    **************
*****************      Fluenta AS    **************
*****************  FGM 160 parameter list **********
*****************                    **************
***************************************************
***************************************************

Operator Console ver.:        1.010

Field Computer, date and time: 2009-04-24   17:13:25

************************************
********** System Parameters **********
************************************
Field Computer Type:          FGM 160
Serial number:                2006-0102
Tag number:                   1-TAG-1
Company:                      FLUENTA AS
Instalation:                  Sandbrekkeveien 85
Description:                  10" LP Flare

System Configuration:         Single system (ch1)
Local Display:                Not installed
SW Version DSP:               0.044
SW-app Version I/O:           1.004
SW-boot Version I/O:          0.006
SW-app Version P&T:           0.256
SW-boot Version P&T:          0.005


****************************************
********** Communication Parameters **********
****************************************

**************** DCS communication **********
----------------------------------------------------------
DCS Modbus Communication:     Enabled
Slave address:                224
Type:                         RTU
Baud rate:                    38400
Databits:                     8
Parity:                       No Parity
Stop bit:                     2
Register Values:              32 bit floating point (IEEE-754)
Register size in request:     32 bits
Register base address:        1000
```

***************** HART communication **********

HART Output Communication:	Enabled
Poll address:	1
Primary Variable:	Total Volume @ Ref. Conditions
Secondary Variable:	Volume Flowrate @ Ref. Conditions
Tertiary Variable:	Temperature
Quaternary Variable:	Pressure

**************** Service port ****************

Slave address:	1
Type:	RTU
Baudrate:	38400
Databits:	8
Parity:	None
Stop bits:	2
Register Values:	32 bit floating point (IEEE-754)

****
************ System Configuration ************
****

Pipe diameter:	0.3800 m
Transducer distance (M):	0.5370 m
Transducer angle:	45.0 deg

******* Units *******

Velocity:	m/s
Volume:	m3
Volume flow:	m3/h (Cubic meter pr. hour)
Mass:	kg
Mass flow:	kg/h
Pressure:	BarA
Temperature:	Celsius

Log time for 24h acc. values:	06:00:00

****
*********** Input Signal Parameters ***********
****

Pressure input	Current Loop (4-20mA)
Temperature input	Current Loop (4-20mA)
Current loop ranges	
Temperature, 4mA value:	255.15 [Kelvin]
Temperature, 20mA value:	533.15 [Kelvin]
Pressure, 4mA value:	1.013 [BarA]
Pressure, 20mA value:	12.044 [BarA]

Current loop calibration coefficients

Temperature, offset:	0.0070
Temperature, scale:	0.9963
Pressure, offset:	0.0220
Pressure, scale:	0.9980

Alarm limits

Temperature, Hi limit:	533.15 [Kelvin]
Temperature, Lo limit:	255.15 [Kelvin]
Pressure, Hi limit:	12.044 [BarA]
Pressure, Lo limit:	1.013 [BarA]

****

********** Output signal parameters **********

****

******** Current loops, 4-20mA ********

Current loop 1, Parameter:	Volume Flowrate @ Act. Conditions
Current loop 2, Parameter:	Molecular Weight
Current loop 3, Parameter:	Testvalue Current Loop 3
Current loop 4, Parameter:	Testvalue Current Loop 4
Current loop 5, Parameter:	Testvalue Current Loop 5
Current loop 6, Parameter:	Testvalue Current Loop 6

Current loop ranges

Current loop 1, 4mA value:	0.00
Current loop 1, 20mA value:	2124000.00
Current loop 2, 4mA value:	0.00
Current loop 2, 20mA value:	50.00
Current loop 3, 4mA value:	4.00
Current loop 3, 20mA value:	20.00
Current loop 4, 4mA value:	4.00
Current loop 4, 20mA value:	20.00
Current loop 5, 4mA value:	4.00
Current loop 5, 20mA value:	20.00
Current loop 6, 4mA value:	4.00
Current loop 6, 20mA value:	20.00

Current loop calibration coefficients

Current loop 1, offset:	-0.1217
Current loop 1, scale:	0.9980
Current loop 2, offset:	-0.1647
Current loop 2, scale:	1.0045
Current loop 3, offset:	-0.1633
Current loop 3, scale:	1.0018
Current loop 4, offset:	-0.2105
Current loop 4, scale:	1.0025
Current loop 5, offset:	-0.0232
Current loop 5, scale:	1.0078
Current loop 6, offset:	-0.1358
Current loop 6, scale:	1.0058

```
*********************************************
******** Measurement/Signal Parameters *******
*********************************************

CW velocity limit up (CW/Chirp -> Chirp):     15 m/s
CW velocity limit down (Chirp -> CW/Chirp): 14 m/s
Chirp Pattern:                                LinFM
Chirp Limit1 (ArcTan FM -> Lin FM):           25 m/s
Chirp Limit2 ( Lin FM ->ArcTan FM):           50 m/s

Low cutoff velocity:                          0.05 m/s
Max. velocity:                                100 m/s
Min. velocity:                                0 m/s
Max. velocity jump:                           50 m/s

Max. sound velocity:                          500 m/s
Min. sound velocity:                          250 m/s
Max. sound velocity jump:                     70 m/s

Historical sound vel. weight factor:          40.0

Z Standard:                                   1.000
Z Operational:                                1.000
Ref Temperature (std. conditions):            15.00 ºC
Ref Pressure (std. conditions):               1.01325 BarA

*********************************************
******** Sensor Calibration Parameters *******
*********************************************

Serial No, Upstream Transducer (A):           022U-07
Serial No, Downstream Transducer (B):         022D-07

CW frequency:                                 68.00 kHz

*** Transducer delays (calibration coefficients) ***
Chirp upstream:                               31818.0 nsec
Chirp downstream:                             33318.0 nsec
CW upstream:                                  12557.0 nsec
CW downstream:                                12576.0 nsec
Delta CW correction:                          0.0 nsec

---------------- END --------------------------
```

6.2 DCS Modbus Interface Specifications

1. Purpose

This document describes the Modbus RTU Protocol and the Modbus ASCII Protocol, which are implemented in the Fluenta Flare Gas Meter, FGM 160 system. Function codes for operating the system are specified, the various registers are described and examples of Modbus communication are given.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM 160	Flare Gas Meter, Model FGM 160
ASCII	American Standard Code for Information Interchange
RTU	Remote Terminal Unit

2.2 Definitions:

Modbus — A high-level protocol for industrial networks developed by Modicon. It defines a request/response message structure for a client/server environment.

3. General Information

Parameters in the FGM 160 are accessible from a serial interface by using the Modbus protocol. All or just a selected range of parameters in an array can be accessed in a single read or write operation, 62 in RTU mode and 30 in ASCII mode (due to memory restrictions in the FGM 160). Some registers contain 'Read only' parameters, while others contain 'Read / Write' parameters. All registers in the FGM 160 are 32-bit wide. Register values are represented as 32-bit floating point values in IEEE 754 format.

The FGM 160 can be configured for Modbus RTU mode or Modbus ASCII mode. In Modbus RTU mode, each 8-bit byte in a message contains two 4-bit hexadecimal characters. In Modbus ASCII mode, each 8-bit byte in a message is sent as two ASCII characters.

Function Codes **3**, **16** and **8** are implemented.

Function Code	Description
3	Read multiple registers, 32-bit floating point format, single precision (IEEE 754).
16	Write multiple registers, 32-bit floating point format, single precision (IEEE 754).
8	Loopback test. Only sub-function code 0 is implemented (Return Query Data).

NOTE: Registers accessed by Function Code 3 and 16 are 32-bit floating point registers, NOT 16-bit integer registers as defined in the Modbus standard.

The Modbus slave address of the FGM 160 is configurable in the range 1-247 (1 – F7 Hex):

Default Modbus slave address for system 1 and 2 is: **224 (E0 Hex).**

Broadcast address (slave address 0) is **not** supported.

Configuration of the DCS RS 422/RS 485 serial port is:

Parameter	Default Setting	Optional Settings
Mode	RTU	ASCII
Baud rate	19200	2400, 4800, 9600, 38400, 57600
Parity	Even	None, Odd
Number of Data Bits	8	7 (7 data bits shall be used in ASCII mode)
Number of Stop Bits	1	2 (No parity requires 2 stop bits)

3.1 Process Parameter Units

Default and optional parameter units are listed below.

Parameter	Default Unit	Optional Units
Pressure	bar A	kPaA, psiA, kg/cm^2 Abs
Temperature	°C	°F
Flow velocity / Velocity of Sound	m/s	ft/s
Volume flow rate at standard conditions	Sm^3/h	MMSCFD
Volume flow rate at actual conditions	m^3/h	MMCFD
Accumulated volume at standard conditions	Sm^3	MMSCF
Accumulated volume at actual conditions	m^3	MMCF
Mass flow rate	kg/h	lbs/h
Accumulated mass	kg	lbs
Gas density	kg/m^3	--

4. Registers

4.1 Modbus Register Base Addresses

The FGM 160 Modbus register base addresses are shown below. These are individually configurable in the range 0 - 65333. However, the offset between succeeding register base addresses should at least be 200 if system 1 and system 2 is configured with the same Modbus slave address.

Modbus Register	Default Base Address
DCS register, System 1	1000
DCS register, System 2	2000

The Modbus Register Base Addresses can be read from registers at the fixed register addresses 65534 and 65535:

Modbus Register Base Address, System 1: 65534
Modbus Register Base Address, System 2: 65535

4.2 Modbus Register Addresses in FGM 160

According to the "Modicon Modbus Protocol Reference Guide" (PI-MBUS-300, Rev.J), ref. 3, the "Holding register" addresses start at 40001. "Holding registers" are accessed by function code 3 (read) or by function code 16 (write) in the FGM 160 Modbus interface.

However, "Holding register address" is not the same as the register address in the data address field of the Modbus message.

The relationship between these addresses is;
"Register address in Modbus message" = "Holding register address" - 40001

Examples:

- Holding register 40001 is addressed as register 0000 in the address field of the Modbus message. (The function code field already specifies a "holding register" operation. Therefore the "4XXXX" reference is implicit.)

- Holding register 40108 is addressed as register 107 in the Modbus message address field.

The register map below refer to the register addresses in the data address field of the Modbus message (not the "Holding register addresses").

Also note that the register addresses given in the register map below are OFFSET addresses relative to the "Modbus Register Base Addresses".

Examples:

- Modbus Register Base Address for system 1 = 1000 and "Register spacing = 1" (default configuration):

  The "Volume Flowrate at Standard Conditions" register for system 1, can be found at address 1008 (1000 + 8). This is the register address in the data address field of the Modbus message, corresponding "Holding register address" will be 41009.

- Modbus Register Base Address for system 2 = 2000 and "Register spacing = 1" (default configuration):

  The "Volume Flowrate at Standard Conditions" register for system 2, can be found at address 2008 (2000 + 8). Corresponding "Holding register address" will be 42009.

- Modbus Register Base Address for system 1 = 1000 and "Register spacing = *2*":

  The "Volume Flowrate at Standard Conditions" register for system 1, can be found at address 1016 (1000 + 16). This is the register address in the data address field of the Modbus message, corresponding "Holding register address" will be 41017.

4.3 FGM 160 Modbus register map for DCS port

Register addresses in register map below are OFFSET addresses relative to the "Modbus Register Base Addresses".

In default configuration these addresses are set to:

1000, for system 1 DCS registers and,
2000, for system 2 DCS registers.

Address columns "RS=1" and "RS=2":

RS=1 : valid for configuration "Register spacing = 1" (default configuration).
RS=2 : valid for configuration "Register spacing = 2".
See section 4.3.4 for detailed description.

4.3.1 System ID Number

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
0	0	ID High word (Production Year)	R	--	2002	2099
1	2	ID Low word (Serial number)	R	--	0	--

4.3.2 Data Time Tag and Primary Measurements Registers

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
2	4	Data Time Tag - Year	R		2002	2091
3	6	Data Time Tag - Month	R		1	12
4	8	Data Time Tag - Day	R		1	31
5	10	Data Time Tag - Hour	R		0	24
6	12	Data Time Tag - Minute	R		0	59
7	14	Data Time Tag - Second	R		0	59
8	16	Volume Flowrate at Standard Conditions	R	Sm^3/h	--	--
9	18	Volume Flowrate at Actual Conditions	R	m^3/h	--	--
10	20	Mass Flowrate	R	kg/h	--	--
11	22	Gas Flow Velocity	R	m/s	--	--
12	24	Gas Flow Velocity w/Threshold	R	m/s	--	--
13	26	Gas Flow Velocity, uncompensated	R	m/s	--	--

4.3.3 Secondary Measurements Registers

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
20	40	Velocity of Sound	R	m/s	--	--
21	42	Gas Density	R	kg/m^3	--	--
22	44	Molecular Weight	R	g	--	--
23	46	Alarm Status *)	R		0	
24	48	Gas Density at Standard Conditions	R	kg/Sm^3	--	--
25	50	Gas density model used	R	----	0	2
26	52	N_2 (nitrogen) fraction	R	%	0	100
30	60	Pressure **)	R/W	bar A		
31	62	Temperature **)	R/W	°C		
32	64	Pressure, HART Transmitter 1	R	bar A		
33	66	Pressure, HART Transmitter 2	R	bar A		
34	68	Temperature, HART Transmitter 1	R	°C		
35	70	Temperature, HART Transmitter 2	R	°C		
36	72	HART Transmitter Status ***)	R		0	6666

***): Alarm Status word (bit coded 16-bit word):**

To interpret the Alarm status bits, the integer part of the register value should first be converted to binary format.

Bit 0: Measurement Error
Bit 1: Flow velocity Alarm
Bit 2: Sound velocity Alarm
Bit 3: Density Alarm
Bit 4: Pressure Alarm
Bit 5: Temperature Alarm

Bit 0 is the Least Significant Bit (LSB).

****): Pressure and Temperature:**

The Pressure and Temperature registers are normally Read Only registers, but the FGM 160 can be configured to accept pressure and temperature data input from DCS through these registers.

*****): HART transmitter status word (4 digit coded, ABCD):**

A Status for pressure transmitter 1 in current system
B Status for pressure transmitter 2 in current system
C Status for temperature transmitter 1 in current system
D Status for temperature transmitter 2 in current system

HART Transmitter Status code:

Code	Description
0	Transmitter not found at initialisation.
1	Status OK.
2	Timeout, transmitter not responding.
3	Wrong code in transmitter response.
4	Checksum error in transmitter response.
5	Wrong data format in transmitter response.
6	Illegal number, NaN (Not A Number).

Example:

Status code = **1620**:

A = 1 : Pressure transmitter 1, status OK.
B = 6 : Pressure transmitter 2, illegal number NaN (Not A Number).
C = 2 : Temperature transmitter 1 timeout, transmitter not responding.
D = 0 : Temperature transmitter 2 not found at initialisation.

4.3.4 Totalized Values Registers

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
40	80	Totalized Volume at Standard Conditions	R	Sm^3	0	1000000
41	82	Totalized Volume at Actual Conditions	R	m^3	0	1000000
42	84	Totalized Mass	R	kg	0	1000000
43	86	Totalized Vol. at Std. Cond. Overflow Count	R	1000000	0	1000000
44	88	Totalized Vol. at Act. Cond. Overflow Count	R	1000000	0	1000000
45	90	Totalized Mass Overflow Count	R	1000000	0	1000000

4.3.5 24-Hour Totalized Values Registers

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
50	100	Last 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
51	102	Last 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
52	104	Last 24 Hour Totalized Mass	R	kg	0	--

Address		Parameter	R/W	Def. Unit	Min	Max
RS=1	RS=2					
53	106	Start Time for Last 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
54	108	(Last-1) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
55	110	(Last-1) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
56	112	(Last-1) 24 Hour Totalized Mass	R	kg	0	--
57	114	Start Time for (Last-1) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
58	116	(Last-2) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
59	118	(Last-2) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
60	120	(Last-2) 24 Hour Totalized Mass	R	kg	0	--
61	122	Start Time for (Last-2) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
62	124	(Last-3) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
63	126	(Last-3) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
64	128	(Last-3) 24 Hour Totalized Mass	R	kg	0	--
65	130	Start Time for (Last-3) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
66	132	(Last-4) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
67	134	(Last-4) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
68	136	(Last-4) 24 Hour Totalized Mass	R	kg	0	--
69	138	Start Time for (Last-4) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
70	140	(Last-5) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
71	142	(Last-5) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
72	144	(Last-5) 24 Hour Totalized Mass	R	kg	0	--
73	146	Start Time for (Last-5) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
74	148	(Last-6) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
75	150	(Last-6) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
76	152	(Last-6) 24 Hour Totalized Mass	R	kg	0	--
77	154	Start Time for (Last-6) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
78	156	(Last-7) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
79	158	(Last-7) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
80	160	(Last-7) 24 Hour Totalized Mass	R	kg	0	--
81	162	Start Time for (Last-7) 24 Hour	R	HH,MMSS	0,0000	23,5959

Address RS=1	Address RS=2	Parameter	R/W	Def. Unit	Min	Max
		Totalisation				
82	164	(Last-8) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
83	166	(Last-8) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
84	168	(Last-8) 24 Hour Totalized Mass	R	kg	0	--
85	170	Start Time for (Last-8) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
86	172	(Last-9) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
87	174	(Last-9) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
88	176	(Last-9) 24 Hour Totalized Mass	R	kg	0	--
89	178	Start Time for (Last-9) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959
90	180	(Last-10) 24 Hour Totalized Volume at Std. Cond.	R	Sm^3	0	--
91	182	(Last-10) 24 Hour Totalized Volume at Act. Cond.	R	m^3	0	--
92	184	(Last-10) 24 Hour Totalized Mass	R	kg	0	--
93	186	Start Time for (Last-10) 24 Hour Totalisation	R	HH,MMSS	0,0000	23,5959

4.3.6 Parameter Unit Registers

Address RS=1	Address RS=2	Parameter	R/W	Def. Value	Optional Settings		
100	200	Unit – Velocity (Gas Flow and Sound)	R	1 (m/s)	2 (ft/s)		
101	202	Unit – Volume	R	1 (m^3)	2 (MMCF)		
102	204	Unit – Volume Flowrate	R	1 (m^3/h)	2 (MMCFD)		
103	206	Unit – Mass	R	1 (kg)	2 (lbs)		
104	208	Unit – Mass Flowrate	R	1 (kg/h)	2 (lbs/h)		
105	210	Unit – Pressure	R	1 (bar A)	2 (kPa A)	3 (psi A)	4 (kg/cm^2 A)
106	212	Unit – Temperature	R	1 (°C)	2 (°F)		

Abbreviations: MMCF : Million Cubic Feet
MMCFD: Million Cubic Feet per Day

4.3.7 Internal System Parameter Registers

AS 1	AS 2	Parameter	R/W	Unit	Min	Max
110	220	Average Transit Time, Upstream	R	ns	0	--
111	222	Average Transit Time, Downstream	R	ns	0	--
112	224	Average Transit Time Difference	R	ns		--
113	226	Transit Time % Used	R	%	0	100
114	228	Transit Time % Used, Upstream	R	%	0	100
115	230	Transit Time % Used, Downstream	R	%	0	00
116	232	Tx Amplitude Upstream	R	V	0	20
117	234	Tx Amplitude Downstream	R	V	0	20
118	236	Rx Amplitude Upstream	R	V	0	20
119	238	Rx Amplitude Downstream	R	V	0	20
120	240	Corr. Env. Peak Level Upstream	R	--	0	20
121	242	Corr. Env. Peak Level Downstream	R	--	0	20
122	244	Chirp Pattern Used	R	--	0	3
123	246	Transducer Temperature, Upstream	R			
124	248	Transducer Temperature, Downstream	R			
125	250	Internal Temperature, FGM Electronics	R			
126	252	Max. Transducer Temperature, Upstream	R			
127	254	Min. Transducer Temperature, Upstream	R			
128	256	Max. Transducer Temperature, Downstream	R			
129	258	Max. Transducer Temperature, Downstream	R			
130	260	Max. Internal Temperature, FGM 160 Electronics	R			
131	262	Min. Internal Temperature, FGM 160 Electronics	R			

4.3.8 Gas Composition Parameter Registers

AS 1	AS 2	Parameter	R/W	Unit	Min	Max
140	280	Mol % - C_1	R/W	%	0	100
141	282	Mol % - C_2	R/W	%	0	100
142	284	Mol % - C_3	R/W	%	0	100
143	286	Mol % - C_4	R/W	%	0	100
144	288	Mol % - C_5	R/W	%	0	100
145	290	Mol % - C_6+	R/W	%	0	100
146	292	Mol % - N_2	R/W	%	0	100
147	294	Mol % - CO_2	R/W	%	0	100

4.3.9 Real Time Clock Registers

AS 1	AS 2	Parameter	R/W	Unit	Min	Max
150	300	RTC Year	R/W	Year	2002	2091
151	302	RTC Month	R/W	Month	1	12
152	304	RTC Day	R/W	Day	1	31
153	306	RTC Hour	R/W	Hour	0	23
154	308	RTC Minutes	R/W	Minute	0	59
155	310	RTC Seconds	R/W	Second	0	59

NOTE:
Not all register parameters listed in Section 4.3.7 and 4.3.8 may be available. They are although listed in order to enable register mapping for future reading of these parameters.

4.4 Data Encoding of FGM 160 Register Values

All registers in FGM 160 are 32 bits wide.
Register values are represented as 32 bits floating point values in IEEE 754 format (single precision).

This is not according to the original Modbus standard [1] which only defines 16 bit wide integer registers.

To access register values in one of the FGM 160 Modbus registers, one of the following methods can be used:

- **Access as one 32 bits registers (default):**
  To use this method, the FGM 160 must be configured for: "Register Size" = 32 bits.
  This means that the "No. of Registers" field in the request from Modbus master, is interpreted as: number of 32 bits registers.
  This method may be known as "Daniel Option".

- **Access as two consecutive 16 bits registers (option):**
  To use this method, the FGM 160 must be configured for: "Register Size" = 16 bits.
  This means that the "No. of Registers" field in the request from Modbus master, is interpreted as: number of 16 bits registers.
  This method may be known as "Modicon Option".
  It may also be necessary to configure the FGM 160 for: "Register spacing = 2", when using this option. (ref. section 4.4.4)

Examples:

1) "Register Size" = 32 bits. Read two (32 bits) registers starting at addr. 12 ($000C_{hex}$):

Request:

Modbus ASCII only	Slave address	Function code	Data Start reg. (MSB)	Data Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Check Sum	Modbus ASCII only
:	E0	03	00	0C	00	02	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave addr.	Function code	Byte count	Data1 (MSB)	Data1	Data1	Data1 (LSB)	Data2 (MSB)	Data2	Data2	Data2 (LSB)	Check sum	Modbus ASCII only
:	E0	03	08	42	F7	66	66	40	10	A3	D7	XX	<CR><LF>

2) "Register Size" = 16 bits. Read one (32 bits) register at addr. 12 ($000C_{hex}$):

Request:

Modbus ASCII only	Slave address	Function code	Data Start reg. (MSB)	Data Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Check Sum	Modbus ASCII only
:	E0	03	00	0C	00	02	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave addr.	Function code	Byte count	Data1 (MSB)	Data1	Data1	Data1 (LSB)	Check sum	Modbus ASCII only
:	E0	03	04	42	F7	66	66	XX	<CR><LF>

4.4.1 Byte Ordering for FGM 160 Register Values

While the byte order is clearly specified for 16 bits integer register values in the Modbus standard [1], there is no specification regarding byte order for 32 bit floating point values.

For addresses and 16 bits data, the Modbus standard [1] defines a "big-Endian" representation. This means that when a numerical quantity larger than a single byte is transmitted, the most significant byte is sent first.

As there are no standard definition regarding byte ordering for transmission of 32 bit floating point values, the FGM 160 can be configured to handle different byte orders.

The FGM 160 can be configured for the following byte orders:
- DCBA (Most Significant Byte first, then Least Significant Byte, default config.)
- ABCD (LSB first, then MSB)
- CDAB (Most Significant Word first, then LSWord)
- BADC (Least Significant Word first, then MSWord, byte swapped)

The examples on previous page are shown with DCBA byte ordering (MSB first), which is the default configuration for FGM 160.

4.4.2 Bit Ordering of Each Character or Byte

The bit order of each character or byte is always in accordance with the Modbus standard, ref. [1].

The Modbus standard [1] defines this as follows:

“Each character or byte is sent in this order (left to right):
Least Significant Bit (LSB)……………. Most Significant Bit (MSB).”

4.4.3 The “Byte Count” Field

The “Byte count” field in Modbus messages specifies how many “8-bit data items” are being transferred in the data section of the message.

In RTU mode, this value is the same as the actual count of bytes in the data section of the message.

In ASCII mode, this value is one-half of the actual count of ASCII characters or bytes in the data section of the message.

4.4.4 Register Address Spacing

By default consecutive register addresses in FGM 160 are spaced by one (ref. FGM 160 Modbus register map for DCS port, section 4.3). Default configuriation of the FGM 160 is: “Register spacing” = 1 (**RS=1**, ref. Tables in section 4.3).

This is sufficient if the DCS system treats the FGM 160 Modbus registers as 32 bits registers (“Daniel Option”, “Register Size” = 32 bits).

But if the DCS system treats the FGM 160 Modbus registers as 16 bits registers (“Register Size” = 16 bits, Modicon Option), this may lead to a register overlap problem internal in the DCS memory. The reason for this is that each 32 bits register in FGM 160, will be read as two consecutive 16 bits registers by the DCS system, and therefore occupy twice as many addresses internal in the DCS system as in the FGM 160 register map.

One way around this problem is to configure the FGM 160 to have all Modbus register addresses spaced by two. This can be done by configuring the FGM 160 for: “Register spacing” = 2 (**RS=2**, ref. Tables in section 4.3).

If the “Register spacing” is set to 2, the correct Modbus addresses can be obtained from column “RS=2” in the register address map, section 4.3.

5. Number Representation

5.1 Single Precision Floating-Point Format

All Modbus register values in the FGM 160 are represented as 32-bit floating-point values according to the IEEE 754 format.

SEEEEEEE EMMMMMMM MMMMMMMM MMMMMMMM

S = signbit; (**0** = positive, **1** = negative.)

EEEEEEEE = the binary exponent + 127 decimal

MMMM......M = mantissa bits. An implicit binary point is placed in front of the first M so that the actual value of the mantissa is less than 1.0.

The value 0.0 is represented with all bits 0.

The value of a binary represented number is

$((-1)^{S}) * (2^{(EEEEEEEE - 127)}) * (1.0 + \text{mantissa})$

Example:

The value 20.0 = $(2^{4}) * (1.0 + 0.25)$

Binary representation gives:

01000001 10100000 00000000 00000000 Binary

or

41 A0 00 00 Hex

----

6. Examples

6.1 Function Code 3, Read registers

(default configuration : « Register size » = 32-bit, byte ordering = DCBA)

Example: Read two (32 bits) registers starting at addr. 1010 ($03F2_{hex}$):

Request:

Modbus ASCII only	Slave address	Function code	Data Start reg. (MSB)	Data Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Check Sum	Modbus ASCII only
:	E0	03	03	F2	00	02	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave addr.	Function code	Byte count	Data1 (MSB)	Data1	Data1	Data1 (LSB)	Data2 (MSB)	Data2	Data2	Data2 (LSB)	Check sum	Modbus ASCII only
:	E0	03	08	00	00	00	00	41	20	00	00	XX	<CR><LF>

Interpretation of reply: Reg. addr. 1010 ($03F2_{hex}$) = 0.0
Reg. addr. 1011 ($03F3_{hex}$) = 10.0

(the IEEE 754 representation of 10.0 is: 41200000_{hex})

6.2 Function Code 16, Write to registers

(default configuration : « Register size » = 32-bit, byte ordering = DCBA)

Example: Set the value of registers addr. 1031 (0407_{hex}) to 10.0:
(the IEEE 754 representation of 10.0 is: 41200000_{hex})

Request:

Modbus ASCII only	Slave addr.	Function code	Start reg. (MSB)	Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Byte count	Data (MSB)	Data	Data	Data (LSB)	Chk. sum	Modbus ASCII only
:	E0	10	04	07	00	01	04	41	20	00	00	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave addr.	Function code	Start reg. (MSB)	Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Chk. sum	Modbus ASCII only
:	E0	10	04	07	00	01	XX	<CR><LF>

6.3 Function Code 8; Diagnostics

6.3.1 Sub-function 0 (Return Query Data)

Note that only sub-function 0 is implemented in FGM 160.

Example: Loopback test (sub-function 0)

Request:

Modbus ASCII only	Slave address	Function code	Sub-func. code (MSB)	Sub-func. code (LSB)	Test Data (MSB)	Test Data (LSB)	Check Sum	Modbus ASCII only
:	E0	08	00	00	00	AA	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave address	Function code	Sub-func. code (MSB)	Sub-func. code (LSB)	Test Data (MSB)	Test Data (LSB)	Check Sum	Modbus ASCII only
:	E0	08	00	00	00	AA	XX	<CR><LF>

7. Exception responses

Different exception responses are implemented in the FGM 160. Some of these exceptions will not occur under normal operation, but the error codes can be useful in a development phase when new software is tested out. In exception response messages, the Modbus slave (FGM 160) sets the MSBit of the Function Code to 1. This makes the Function Code value in an exception response exactly 80_{hex} higher than the value would be for a normal response.

If the FGM 160 receives a request, but detects a communication error (parity, LRC, CRC etc.), no response is returned. The DCS system will then eventually process a timeout condition.

7.1 Standard Modbus Exception Codes

CODE	NAME	DESCRIPTION
1	ILLEGAL FUNCTION	Illegal function code for this slave.
2	ILLEGAL DATA ADDDRESS	The data address is not an allowable address for this slave. More specifically; the combination of start address and no. of registers is invalid.
3	ILLEGAL DATA VALUE	The value contained in the query data field is not allowable for this slave *). More specifically; Function Code 3: No. of registers in request is an illegal value. Function Code 8: Value in the data field of the request is illegal. Function Code 16: No. of registers in request is an illegal value, or "Byte count" value does not match the "No. of registers".

*): It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation (valid data range) of the application program, since the Modbus protocol is unaware of the significance of any particular value of any particular register.

7.2 Fluenta Defined Exception Code

CODE	NAME	DESCRIPTION
128	ILLEGAL REGISTER VALUE	Register value submitted for storage in a register has a value outside the expectation (valid data range) of the FGM 160.

Example: Illegal data address in request (addr. 15000 ($3A98_{hex}$)

Request:

Modbus ASCII only	Slave address	Function code	Data Start reg. (MSB)	Data Start reg. (LSB)	No. of Regs. (MSB)	No. of Regs. (LSB)	Check Sum	Modbus ASCII only
:	E0	03	3A	98	00	02	XX	<CR><LF>

Reply:

Modbus ASCII only	Slave address	Function code	Exception code	Check Sum	Modbus ASCII only
:	E0	83	02	XX	<CR><LF>

8. Physical Layer

The Modbus electrical interface at FGM 160 is in accordance with EIA/TIA-485 (also known as RS485 standard). This standard allows point to point and multipoint systems, in a "two-wire" or "four-wire" configuration.

8.1 RS422 Compatible Master Node (DCS)

The electrical characteristics for RS485 are specified such that they cover requirements of RS422.
This allows RS485 compliant drivers/receivers to be used in most RS422 compliant applications, but the reverse is not necessarily true.

As the RS422 interface require a dedicated pair of wires for each signal, a transmit pair and a receive pair, this compatibility is only applicable in four-wire configurations. Four-wire systems often use an RS422 master (the driver is always enabled) and RS485 slaves to reduce system complexity.

In four-wire configuration, the FGM 160 accepts an RS422 master (DCS system).

8.2 Two-Wire Configuration (default configuration)

In two-wire configuration, the transmit and receive signals share a single pair of wires for half-duplex communications. In fact a third conductor must also interconnect all the devices of the 2W bus: the common conductor.

To avoid conflicts on the communication line, only one driver is allowed to transmit on the line at any time.

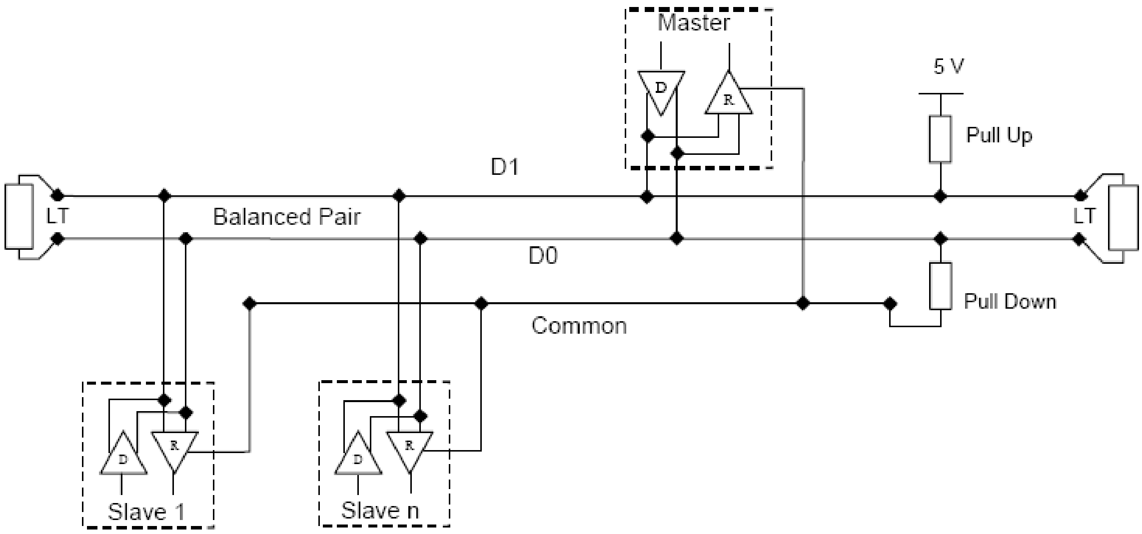


Figure 62 – General 2-Wire Topology.

2-Wire Modbus Circuits Definition:

Signal on Master (DCS)		EIA/TIA-485 Name	Signal on Slave FGM 160	Description
Name	**Type**			
A(-)	Out/in	A	DCS-T- / DCS-R-	Inverted signal ($V_A>V_B$ » "0")
B(+)	Out/in	B	DCS-T+ / DCS-R+	Non-inverted signal ($V_A<V_B$ » "1")
Common	Common	Signal GND	DCS-GND	Common conductor

8.3 Four-Wire Configuration

In four-wire configuration, the transmit and receive signals use separate pairs of wires for possible full-duplex communication. In fact a fifth conductor must also interconnect all the devices of the 4W bus: the common conductor.

To avoid conflicts on the communication line in "Multipoint" systems, only one driver is allowed to transmit on the line at any time. "Multipoint" system is defined as system with more than one slave device driver(i.e. systems with one master and two or more slaves).

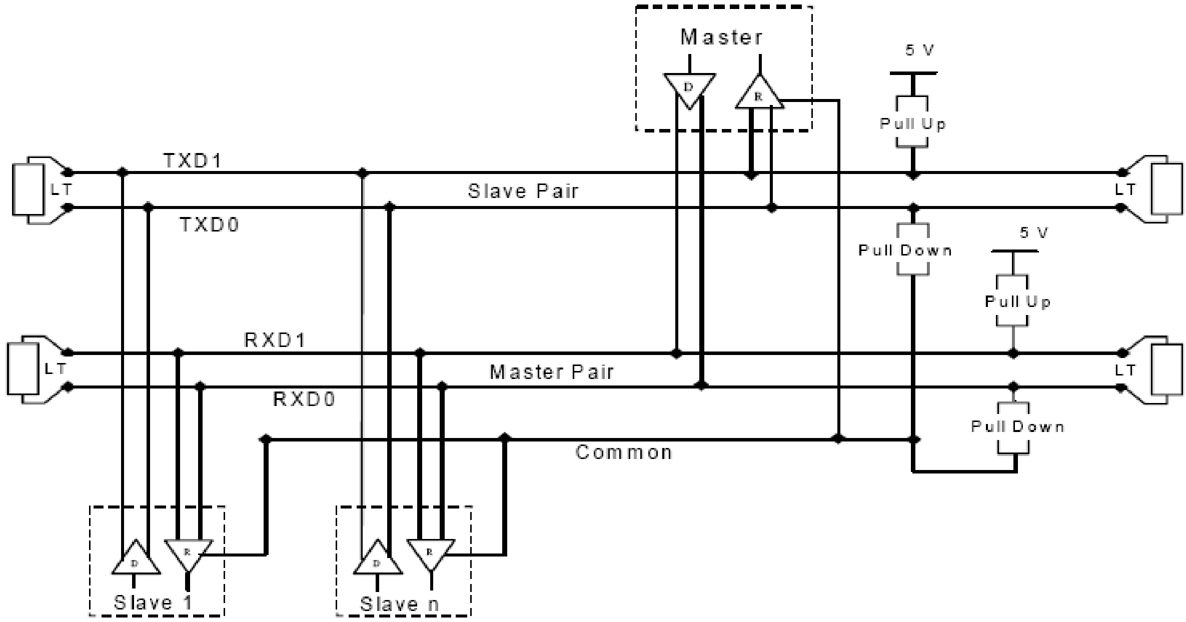


Figure 63 – General 4-Wire Topology.

4-Wire Modbus Circuits Definition:

Signal on Master (DCS)		EIA/TIA-485 Name	Signal on Slave FGM 160	Description
Name	**Type**			
T-A(-)	Out	A	DCS-R-	Inverted signal ($V_A>V_B$ » "0")
T-B(+)	Out	B	DCS-R+	Non-inverted signal ($V_A<V_B$ » "1")
R-A(-)	In	A'	DCS-T-	Inverted signal ($V_A>V_B$ » "0")
R-B(+)	In	B'	DCS-T+	Non-inverted signal ($V_A<V_B$ » "1")
Common	Common	Signal GND	DCS-GND	Common conductor

The 4-W cabling must cross the two pairs of the bus between the master (DCS) and the slave (FGM 160). That means that the Tx lines from the master must be connected to the Rx terminals of the slave (FGM 160), and vice versa.

8.4 Cable Specifications

The Modbus Serial Line Cable must be shielded. At one end of each cable its shield must be connected to protective ground.

A 2-wire system must use a balanced pair and a third conductor for the Common (signal GND).

An optionally 4-wire system must use two balanced pair and a third conductor for the Common (signal GND).

Wire Gauge:
Wire gauge must be chosen sufficiently wide to permit the chosen combination of baud rate and cable length. AWG24 (0.22 mm^2) is normally sufficient.

Characteristic Impedance:
A value higher than 100 Ω may be preferred, especially for 19200 and higher baud rates. Recommended characteristic impedance is: 120 Ω.

Shunt Capacitance (pF/ft):
One of the factors limiting total cable length is the capacitive load.
Systems with long cable lengths benefit from using low capacitance cable (<16pF/ft).

Cable length:
The end to end length of the Modbus communication cable must be limited.
The maximum length depends on the baud rate, the cable (Gauge, Capacitance or Characteristic Impedance), the number of loads on the daisy chain, and the network configuration (2-wire or 4-wire).

For a maximum 9600 Baud Rate and AWG26 (or wider) gauge, the maximum length is app. 1000m. (AWG26 = app. 0.14 mm^2)

Grounding:
The "Common" conductor (signal GND) must be connected directly to protective ground, preferably at one point only for the entire bus. Generally this point is close to the master device (DCS system).

Line termination:
Line terminations may be required for high baud rates and long distance.
If line terminations are required, termination resistors should be placed only at the extreme ends of the communication line(s).

The value of the termination resistors should match the characteristic impedance of the communication line. Typically value is: 120 Ω (should not be < 90 Ω).

Line Polarization:
The FGM 160 does not need any line polarization resistors (pull–up/pull-down resistors).
The RS485 receiver (DCS Modbus receiver) at FGM 160, feature fail-safe circuitry which guarantees a logic-high receiver output when the receiver inputs are open or shorted. This means that the receiver output will be a logic high (passive level) if all transmitters on a transmission line are disabled (high impedance).

8.5 Visual diagnostic

If the FGM 160 is equipped with a display (optional), the Modbus communication status may be observed by one of the LEDs beneath the display area (Communication LED). Another LED indicates power applied to the FGM 160 (Power LED).

Indication (Color)	**State**	**Description**
Comm. LED (Green)	Communication	Switched ON during frame reception or sending.
Comm. LED (Red)	Error	Flash: Modbus communication fault
Power LED (Green)	Device status	Switched ON: device powered

8.6 RS485 Modbus Connections at FGM 160

Screw terminals are used for Modbus RS485 / RS422 connections in the FGM 160.

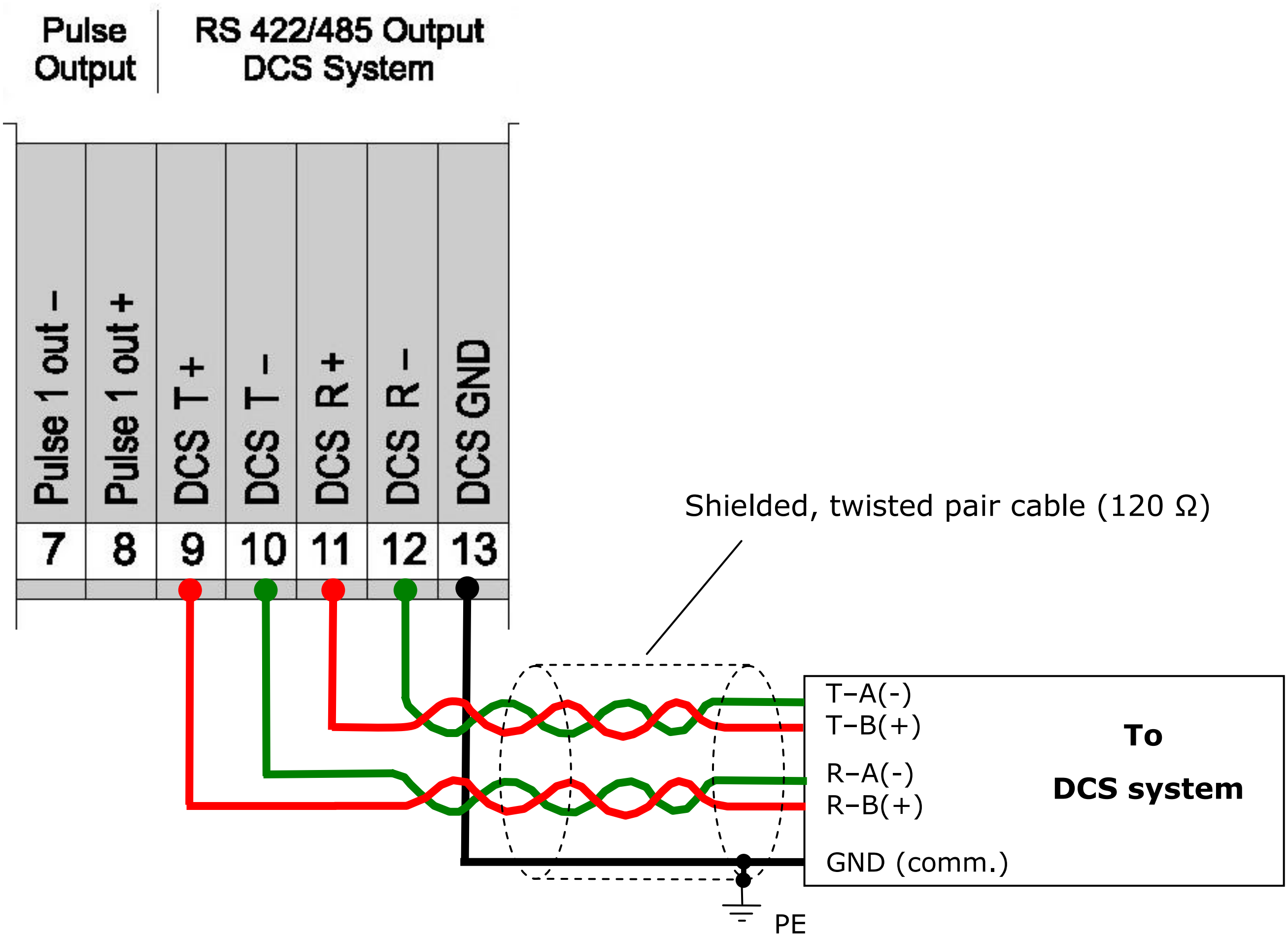


Figure 64 4-wire RS 485 interface between the FGM 160 and the DCS system.

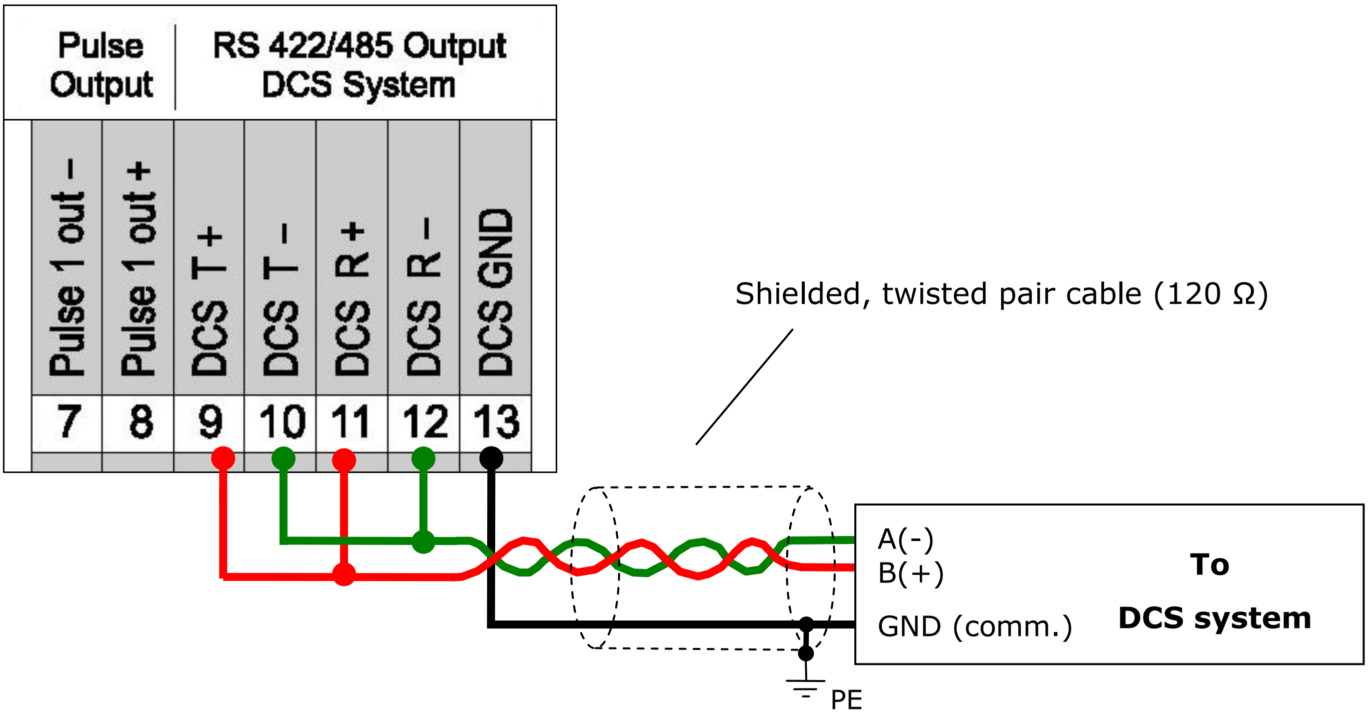


Figure 65 2-wire RS 485 interface between the FGM 160 and the DCS system.

In order to connect FGM 160 to a two-wire physical interface, the following modifications should be done:

- The "DCS - R-" terminal and the "DCS - T-" terminal shall be wired together.
- The "DCS - R+" terminal and the "DCS - T+" terminal shall be wired together.

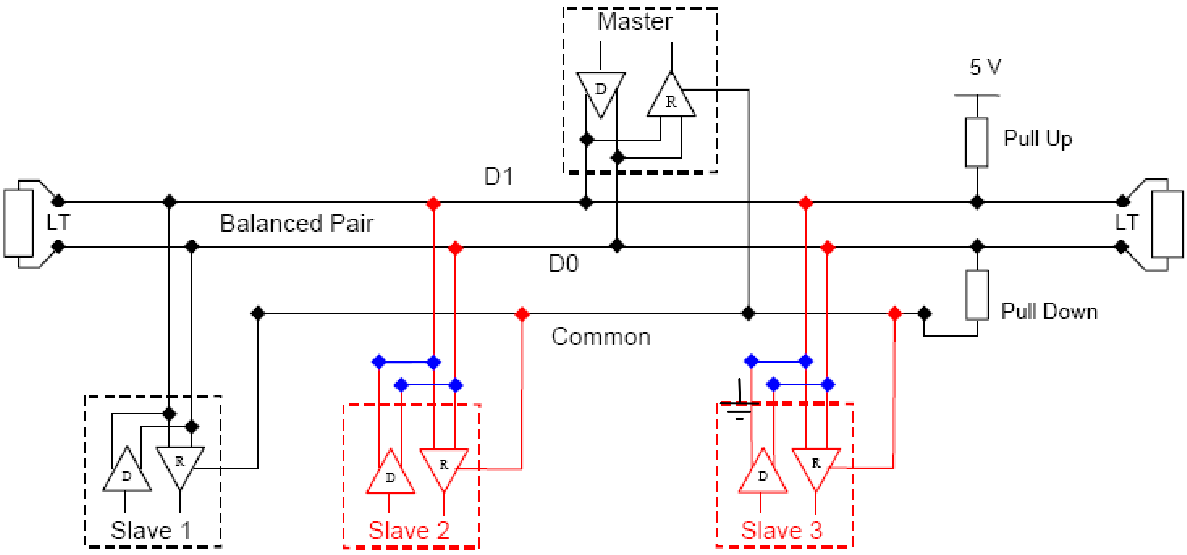


Figure 66 – Connecting devices with 4-Wire interface to a 2-Wire cabling system.

9. References

1. Modbus Application Protocol Specification V1.1b, (Dec. 28, 2006).

2. Modbus over serial line, Specification and Implementation Guide V1.02, (Dec. 20, 2006).

3. Modicon Modbus Protocol reference Guide, PI-MBUS-300 Rev. J, (June 2006).

4. B&B electronics, Technical Article #11, Cable Selection for RS-422 and RS-485 systems, (January 1999).

5. Linear Technology, LTC2859/LTC2861 datasheet.

6.3 HART Output Interface Specification

1. Purpose

This document describes the communication interface for the HART output channel of the Fluenta Flare Gas Meter, FGM 160.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM	Flare Gas Meter
HART	Highway Addressable Remote Transducer

2.2 Definitions:

HART	A widely used extension to the 4-20 mA analogue signal used in sensor networks. HART superimposes a 1,200 bits/second digital signal onto the line that provides bi-directional communications with intelligent devices.

3. General Information

3.1 HART Physical Layer

HART uses a frequency-shift keying to superimpose digital communication at 1200 baud on to the 4 to 20 mA current loop. Two different frequencies are used to represent binary 1 and 0 (1200 Hz and 2200 Hz respectively).

The average value of the superimposed HART signal is zero, so no d.c. component is added to the existing 4 to 20 mA signal. Thus the analogue 4 to 20 mA signal may be used in addition to the HART communication.

However, this is only possible in point to point configuration. In multidrop configuration the analogue 4 to 20 mA signals from every transmitter would add together and give a meaningless total current. The analogue 4 to 20 mA signal is therefore parked at 4 mA in multidrop configuration (this also reduces the total power requirement).

3.1.1 Multidrop Operation

Up to 15 slave devices can be connected to a single multidrop pair of wires.
Each of the slaves must have a unique address.

3.1.2 Connection Loop

3.1.2.1 Load Resistor

The power supply is almost a short circuit at the HART signalling frequencies, so a communicating device cannot be connected directly across it. To avoid this problem, a load resistor must be inserted in the current loop. The communicating device can then be connected either across the transmitter or across the load resistor.
The HART specification allows load resistors between 230 and 1100 Ω.

3.1.2.2 Cabling

The field wiring of a HART system should use a screened twisted pair cable.
Preferably individually-screened twisted pairs should be used to avoid possible crosstalk between pairs.

3.1.2.3 Signal Attenuation and Distortion

Due to relatively low frequencies, the cable attenuation and delay distortion become moderate. This implies that HART communication can be performed up to a distance of 1500 meters or more, provided that the RC time constant of the cable and the connected devices is 65 µsec. or less.

Since the maximum length of the HART communication line (limited by the RC time constant) is much smaller than the wavelength of the HART signal (app. 120 km), the practical HART networks don't act like transmission lines and there is no need for impedance matched cables or terminations.

The limiting factors are the loop-capacitance and loop–resistance.
The capacitance and resistance in the loop forms a single pole filter with a cut off frequency of: $1/(2\pi RC)$. For long cable lengths (high capacitance) the filter cut-off can be close to the HART signal frequency. The result of this is a possible distortion of the HART signal.
To avoid this kind of distortion, the HART specification imposes a minimum cut-off frequency of 2500 Hz (at 3 dB attenuation), slightly above the highest HART signalling frequency. A simple resistance-capacitance circuit will meet this requirement if it has an RC time constant value of 65 µsec. or less.

The loop resistance mainly consists of the loop resistor, but the cable resistance will also give a contribution. For long cable lengths, the loop capacitance consists mainly of the cable capacitance. Device capacitance will also contribute a bit, especially in multidrop networks with several devices connected in parallel. HART specifications recommend 5000 pF as a maximum value for device shunt capacitance.

3.2 HART Data Link Layer

HART is a half duplex "master-slave" protocol. This means that each message transaction is originated by the HART master; the slave (field) device only replies when it receives a command message addressed to it.

3.2.1.1 Burst Mode

To achieve a higher data rate, a field device may implement an <u>optional</u> "burst mode".
When switched into this mode the field device repeatedly sends a data message back to the master.

3.2.1.2 Multimaster Operation

The HART protocol allows for two active masters in a system, one "primary" and one "secondary". Usually, the primary master would be the control system and the secondary master would be for instance a handheld communicator. The two masters have different addresses, so each can positively identify replies to its own command.
After each transaction is completed, the master should pause for a short time before sending another command, to allow an opportunity for the other master to break in if it wishes.

3.2.1.3 Data Throughput

Typical message lengths allow for maximum two transactions per second.
In burst mode more than three messages can be transmitted per second.

In multidrop networks, data throughput remains the same as for point-to-point configuration (max. app. 2 transactions per second). However, latency increases and is proportional to the number of devices in the network.

Example: in a multidrop network with 4 devices, the latency will be app. 2 seconds (i.e. the update rate for each device is app. 2 sec.).

3.2.1.4 Character Coding

Character format: 1200 baud, 8 data bits, odd parity, 1 stop bit.

3.3 HART Commands (Application Layer)

HART commands are defined in three groups: "universal", "common-practice" and "device-specific".

"Universal commands" provide functions which are implemented in all HART compliant field devices.

"Common-practice commands" provide functions common to many field devices, but not all.

"Device-specific commands" provide functions which are more or less unique to a particular field device.

3.4 HART Device Drivers

3.4.1 Device Description (DD)

A Device Description (DD) is a device driver for specific features and functions of a HART device.

A Device Description (DD) is an electronic data file prepared in accordance with Device Description Language specifications that describes specific features and functions of a device including details of menus and graphic features to be used by host applications to access all parameters and data in the corresponding device.

The DD identifies which common practice commands are supported as well as the format and structure of all device-specific commands.

A DD is an optional element of the HART communication technology and is not required to communicate with a HART device. DD are mostly used for device set-up and not required for routine device communication.

3.4.2 Device Type Manager (DTM)

A Device Type Manager (DTM) is the device driver for the FDT standard.

FDT (Field Device Tool) is an interface specification that standardizes the data exchange between field devices and the system level (FDT frame application).

FDT frame applications can be device configuration tools, control systems, operator consoles or asset management tools etc.

Examples of FDT frame applications are: PACTware, FieldCare (E+H), ControlBuilderF (ABB), fdtContainer (M&M Software).

FDT is communication independent and can be used with any communication protocol (e.g. HART, Modbus, Profibus, Foundation Fieldbus, etc.).

An appropriate DTM for every instrument of every supplier is not yet available. If no specific DTM exists for a HART-capable field device, a generic HART DTM can be used. The universal and common-practice commands based on the HART specification that are used by most HART devices on the market are supported by the generic DTM. Generic HART DTM is available from various companies (e.g. ICS GmbH).

4. FGM 160 HART Functionality

4.1 HART Output Channel

One of the current loop outputs of FGM 160 can be configured and used for HART communication. The other current loop outputs have no HART functionality.

The HART output channel can be configured as a passive output (external loop power) or as an active output (powered from FGM 160).

4.2 HART Compliance

At the moment, the FGM 160 <u>only</u> supports a limited selection of the HART universal command and is therefore <u>not</u> fully HART compliant.

No common-practice, or device-specific commands are supported by the FGM 160.

4.3 Device Drivers

As no device-specific commands are supported by the FGM 160, there is no need for a special device driver in order to communicate with the device.

Therefore no specific Device Description (DD) or Device Type Manager (DTM) is available for the FGM 160.

4.4 Supported HART Commands

The following HART universal commands are supported by FGM 160:

Table 5 - Supported HART commands

HART command #	Function
0	Read unique identifier.
1	Read primary variable.
2	Read current and percent of range.
3	Read current and four (predefined) dynamic variables.
12	Read message.
13	Read tag, descriptor, and date.
16	Read final assembly number.

NOTE:
The FGM 160 does not support any HART write commands and it is therefore not possible to configure the device via the HART interface.

For configuration of the FGM 160, the FGM 160 Operator & Service Console must be used. This software communicates with the FGM 160 through the dedicated RS-485 service port.

4.5 HART Poll Address

The FGM 160 can be set up with a HART poll address in the range 0 to 15.

The default HART poll address for the FGM 160 is:

1 (Optional addresses: 0 – 15).

4.6 Multidrop Mode

The FGM 160 supports multidrop mode.

If the HART poll address is set to a value other than 0, the analogue current loop signal is set to a fixed value of 4 mA. The device is then parked and enabled for multidrop operation.

If the HART poll address is set to 0, analogue 4 to 20 mA signal may be used in addition to the HART communication.

4.7 Burst Mode

The FGM 160 does not support the optional "burst mode" operation.

4.8 HART Output Parameters

Parameters available as HART variables are listed in the table below.
This table contains a limited selection of the FGM 160 DCS Modbus registers (available through the RS-485 DCS port).

Any of these parameters can be selected for HART Primary variable (PV), Secondary variable (SV), Third variable (TV) and Fourth variable (FV).

The selected parameters will be available for read-out through HART command 1 (PV) and HART command 3 (PV, SV, TV and FV).

For configuration of the HART output parameters, the FGM 160 Operator & Service Console must be used.

Table 6 - HART Output parameters.

Parameter	Def. unit	Min	Max	Modbus reg. no:
Volume Flowrate at Reference Conditions	Sm^3/h *)	--	--	8
Volume Flowrate at Actual Conditions	m^3/h *)	--	--	9
Mass Flowrate	kg/h *)	--	--	10
Gas Flow Velocity	m/s *)	--	--	11
Gas Flow Velocity w/Threshold	m/s *)	--	--	12
Gas Flow Velocity, uncompensated	m/s *)	--	--	13
Velocity of Sound	m/s *)	--	--	20
Gas Density	kg/m^3	--	--	21
Molecular Weight	g	--	--	22
Alarm Status	--	0		23
Pressure	bar A *)			30
Temperature	°C *)			31
Pressure, HART Transmitter 1 1)	bar A *)			32
Pressure, HART Transmitter 2 2)	bar A *)			33
Temperature, HART Transmitter 1 1)	°C *)			34
Temperature, HART Transmitter 2 2)	°C *)			35
Totalized Volume at Reference Conditions	Sm^3 *)	0	999999	40
Totalized Volume at Actual Conditions	m^3 *)	0	999999	41
Totalized Mass	kg *)	0	999999	42
Totalized Vol. at Ref. Cond. Overflow Count	1000000	0	1000000	43
Totalized Vol. at Act. Cond. Overflow Count	1000000	0	1000000	44
Totalized Mass Overflow Count	1000000	0	1000000	45
Last 24h Accumulated Volume at Ref. Cond.	Sm^3 *)	0	--	50
Last 24h Accumulated Volume at Act. Cond.	m^3 *)	0	--	51
Last 24h Accumulated Mass	kg *)	0	--	52
Transit Time % Used, Upstream	%	0	100	114
Transit Time % Used, Downstream	%	0	100	115
Internal Temperature, Electronics	°C *)			125

Notes:

1): Data from HART Transmitters is only applicable for FGM 160 systems configured for HART Pressure and Temperature transmitters.

2): Data from HART Transmitter 2 is only applicable for FGM 160 systems configured for double HART transmitters.

*): Optional units:

Table 7 – HART output parameter, optional units.

Parameter	Optional units
Volume flowrate	MMCFD (Million Cubic Foot per Day), MMSCFD (Million Standard Cubic Foot per Day)
Mass flowrate	lbs/h
Velocity	ft/s
Pressure	kPa A, psi A, kg/cm^2 Abs
Temperature	°F
Acc./totalized volume	MMCF, MMSCF
Acc./totalized mass	lbs

For configuration of HART output parameters units, the FGM 160 Operator & Service Console must be used.

All HART variable values will be transmitted as floating-point numbers, 32-bit single precision (IEEE 754), according to HART specification HCF_SPEC-127.

4.8.1 HART Variable Unit Codes

The HART variable unit code(s) is included in the reply of HART command 1 (read primary variable) and HART command 3 (read current and four dynamic variables).
The following HART unit codes are implemented in FGM 160:

Table 8 - HART unit codes.

Engineering unit	HART unit code
m^3/h	19
MMCFD	242 *)
kg/h	75
lbs/h	82
m/s	21
ft/s	20
kg/m^3	92
g	60
bar A	7
kPa A	12
psi A	6
kg/cm^2 Abs	10
°C	32
°F	33
m^3	43
MMCF	243 *)
kg	61
lbs	63
%	57
-- (none)	251

Note:
*): Unit codes 242 and 243 are manufacturer specific definitions.

4.9 HART Interface Connection

4.9.1 Active Output (Loop is Powered from FGM 160)

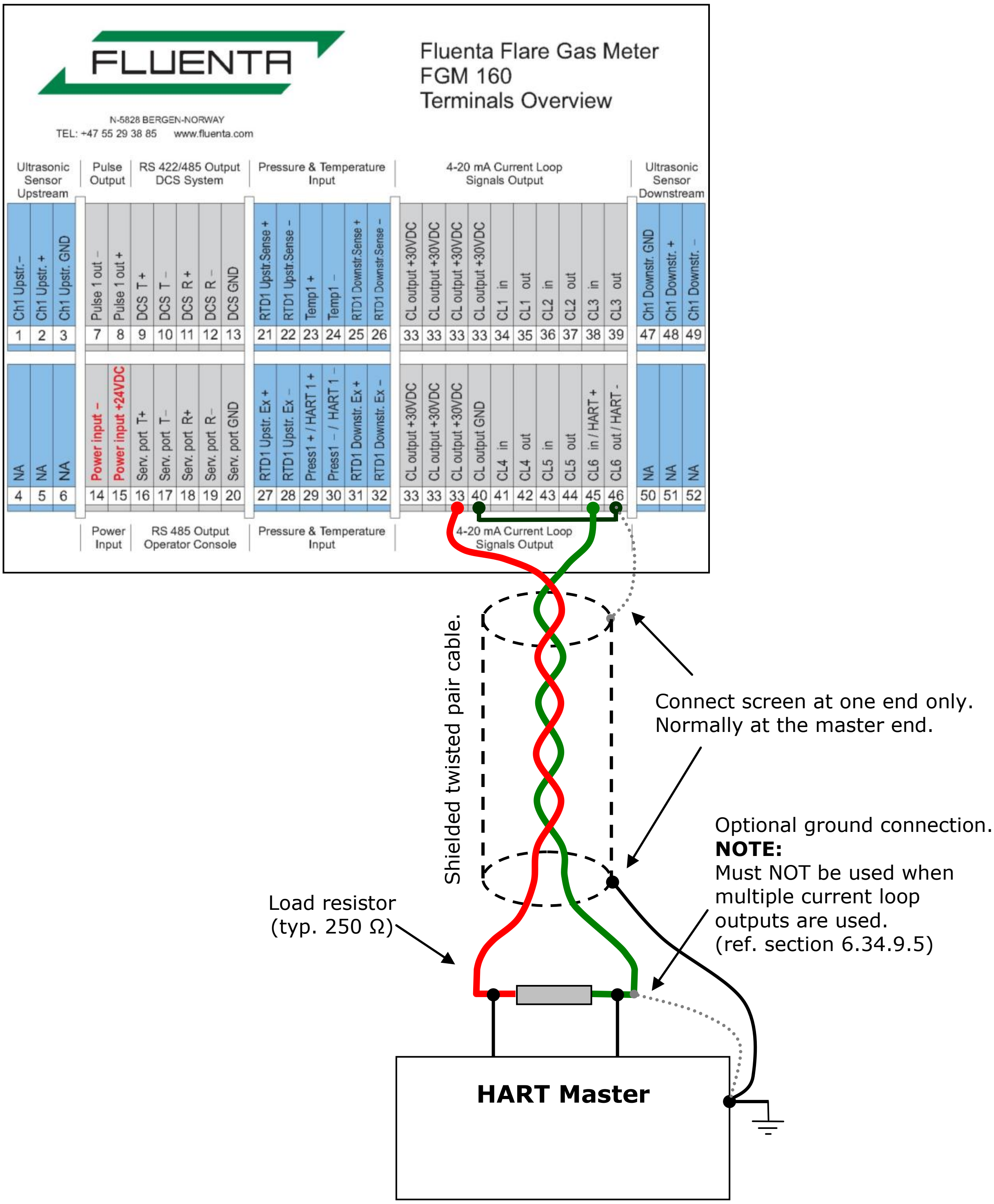


Figure 67 HART connection with active output configuration.

4.9.2 Passive Output (Loop is Powered from HART Master/DCS System)

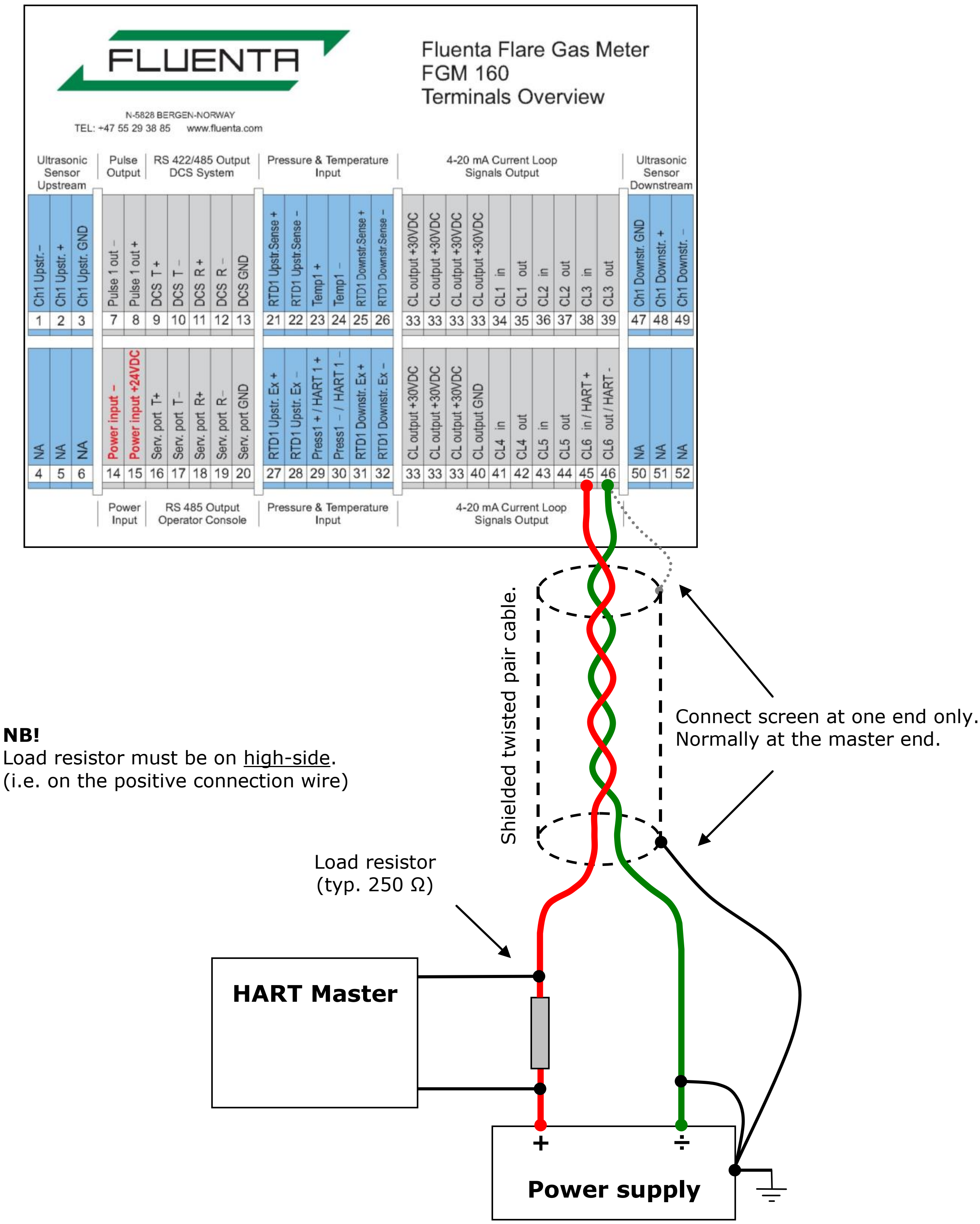
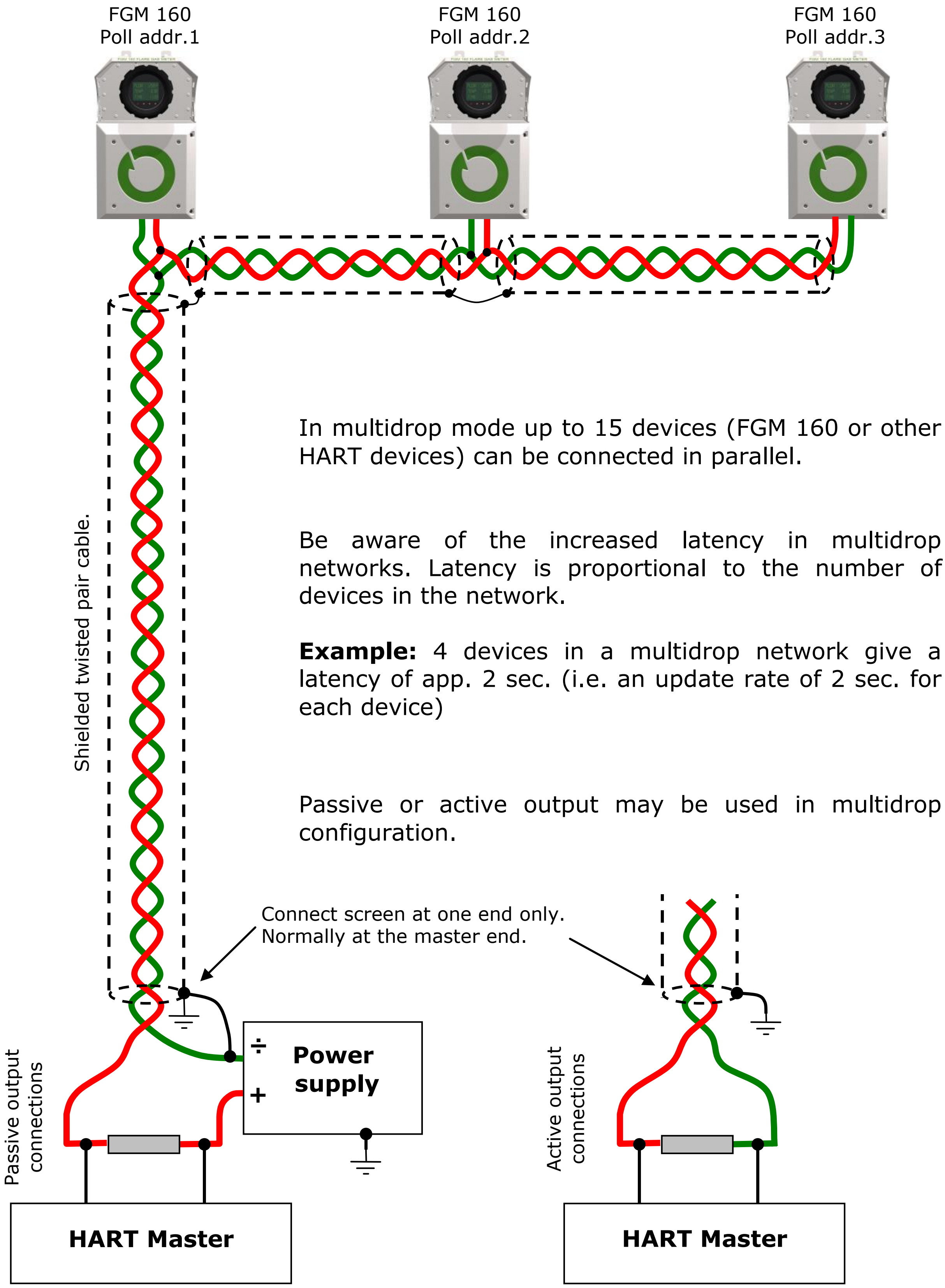


Figure 68 **HART output with passive output configuration.**

4.9.3 Multidrop Connections



In multidrop mode up to 15 devices (FGM 160 or other HART devices) can be connected in parallel.

Be aware of the increased latency in multidrop networks. Latency is proportional to the number of devices in the network.

Example: 4 devices in a multidrop network give a latency of app. 2 sec. (i.e. an update rate of 2 sec. for each device)

Passive or active output may be used in multidrop configuration.

Figure 69 HART multipoint connection (multidrop).

4.9.4 Galvanic Isolation

The HART output terminals (as well as the other current loop outputs) are galvanic isolated from the rest of the FGM 160 electronics.

However, the individual current loop outputs are not isolated with regards to each other. (i.e. the HART output terminals are not isolated from the other current loop outputs of the FGM 160).

4.9.5 Grounding

To prevent interference by external signals, it is important to ground the system properly.

The cable screen must be connected to ground at one point only. This single ground point will normally be at or near the primary master (for example, the control system). The screen is left open at the other end (normally field instrument end) to avoid the conduction of ground currents.

The signal loop should be grounded at one point or may be ungrounded (floating) if electrical noise is minimal. If the signal loop is grounded, the negative signal wire should be connected to ground, preferably at the same point as the cable screen.

Special precautions for FGM 160:
When multiple current loop outputs are used in active output configuration, the signal loops must NOT be grounded, as this will cause erroneous readings of all current loop outputs (ref. note in Figure 67, optional ground connection).

This is however not a problem in;

- passive output configuration and,
- active output configuration with only one current loop in use.

4.9.6 Load / Loop Voltage Limitations

HART specification requires a loop resistance between 230 and 1100 Ω.

4.9.6.1 Active Output Configuration

In active output configuration the loop voltage is 30 V.
According to Figure 70, the load limitation at 30 V is min. 230 Ω and max. 1100 Ω.

4.9.6.2 Passive Output Configuration

In passive output configuration the load limitation is dependent upon the external loop voltage.

Loop voltage:	min. 7.6 V, max. 50 V	
Load resistor:	U = 25 to 33 V:	R_{load}: min. 230 Ω, max. 1100 Ω.
	U < 25 V:	R_{load}: min. 230 Ω, max.: (U-3 V) x 50.
	U > 32.6 V:	R_{load}: max. 1100 Ω, min.: (U-28 V) x 50.

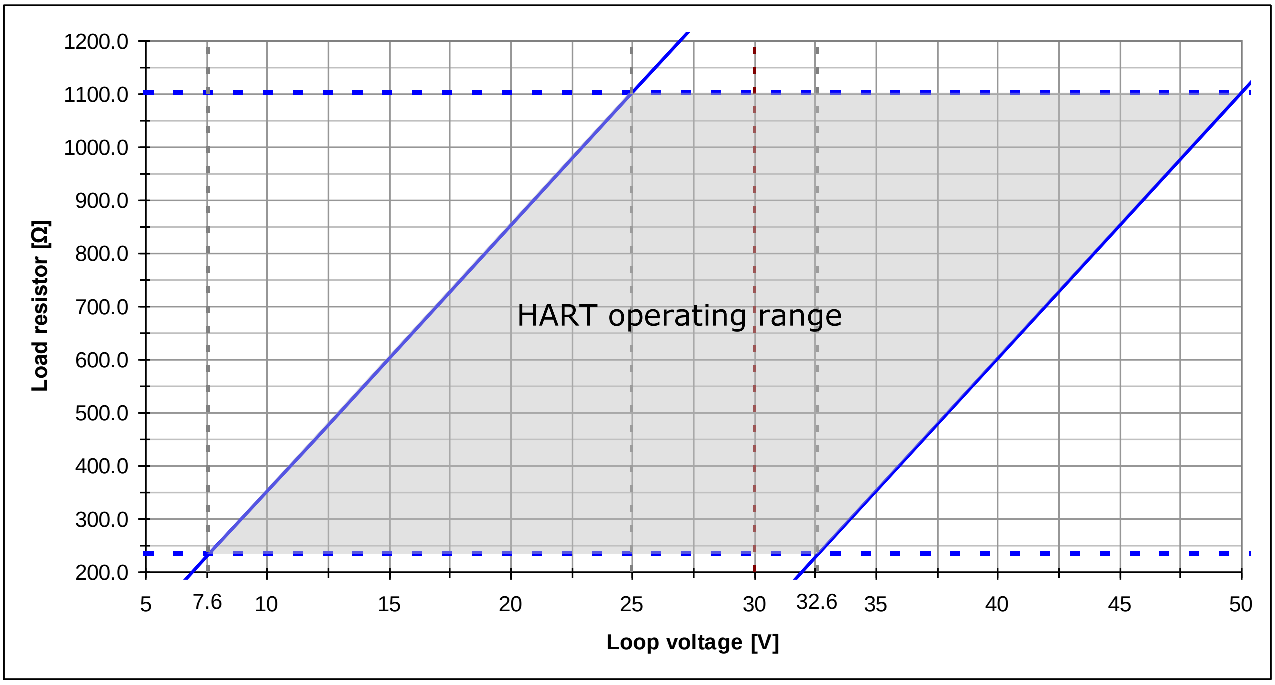


Figure 70 Load / voltage limitations.

Table 9 Min. /max. load resistor value at typical loop voltages.

Loop voltage	R_{load} min.	R_{load} max.
12 V	230 Ω	450 Ω
24 V	230 Ω	1050 Ω
36 V	400 Ω	1100 Ω
48 V	1000 Ω	1100 Ω

4.9.6.3 Selection Criteria of Load Resistor Value

- Cable length: To achieve maximum useful cable length, select the smallest allowable load resistor value according to Figure 70.
- Signal level: The load resistor value may be increased if the signal level of slave response is low. (should be min. 120 mV p-p).
- Loop voltage: For loop voltages above 32.6 V it may be necessary to increase the load resistor value due to power rating limitations of the FGM 160 current loop outputs (ref. Figure 70).

4.9.7 Cabling

Low capacitance, individually screened, twisted pair cable with min. 0.5 mm^2 cross section (AWG 20) is recommended.

For shorter distances, 0.2 mm^2 (AWG 24) twisted pair with common screen can be used.

4.9.7.1 Maximum Cable Length

The following rule of thumb can be used to determine the app. maximum loop length:

Max. length = 65 x 10^6 / (R x C) – (Nx5000+10000)/C

where; R is the total loop resistance in Ω
C is the cable capacitance in pF/m (or nF/km)
N is the number of slaves connected in parallel (multidrop)

A low loop resistor value will help to increase the max. loop length (however, the lower limit in HART specification is 230 Ω).

Multidrop operation reduces the possible cable length, since the capacitance of the field devices increases the total C (and the RC time constant).

Example: Point-to-point configuration (one slave device)
Cable: RFOU(i) instr. cable, 0.75 mm^2 (115 nF/km, 25 Ω/km)
Load resistor: 270 Ω

Max. cable length ≈ 65 x 10^6 / ((270+75) x 115) – 15000/115 ≈ 1500 m

Note:
The total loop resistance consists of load resistor + cable resistance (both conductors in series).
The cable capacitance is the capacitance measured from one conductor to all others and screen (not between the two conductors of a pair, as commonly quoted).

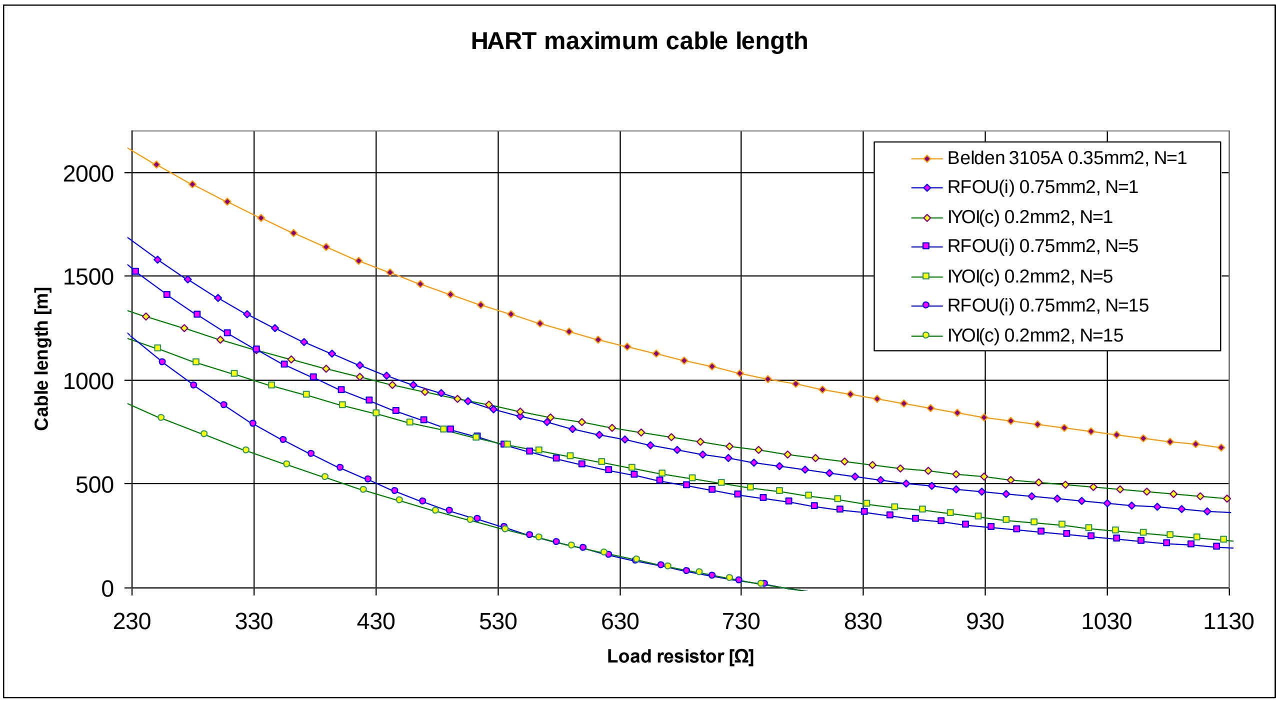


Figure 71 HART maximum cable length.

Cable parameters used in Figure 71:	RFOU(i) 0.75 mm^2:	115 pF/m,	25 Ω/km
	IYOI(c) 0.2 mm^2:	90 pF/m,	95 Ω/km
	Belden 3105A 0.35 mm^2:	66 pF/m,	49 Ω/km

5. REFERENCES

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[3] About HART, By Analog Services, Inc., Part 2: Practical Stuff (rev. 8-9-99)

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[10] HART Protocol, Common Tables, HCF_SPEC-182, rev.7.0

[11] Datasheet, Draka Norsk kabel, RFOU_i_250V_IEC60092-376

[12] Datasheet, Draka Norsk kabel, IYOI(c)_0,5mmØ.e01.doc

[13] Datasheet, Belden, 3105A Multi-Conductor – EIA Industrial RS-485 PLTC/CM, 03-16-2009

6.4 Operator Console Description

1. Purpose

The purpose of this document is to give a detailed description of how the Operator & Service Console (O&SC) operates. This document will only cover the section related to the Operator interface, as the Service section applies to Fluenta support personnel only. The interface between the FGM 160 and the O&SC will be described, with local and remote operation. Further, the menu and windows based O&SC software will be outlined with detailed description of each program window.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM	Flare Gas Meter
O&SC	Operator & Service Console

3. General

3.1 Interface Between FGM 160 and O&SC

The O&SC can be interfaced to the FGM 160 either by 2- or 4-wire RS 485 or 4-wire RS 422. The communication protocol setup is fixed at:

Baudrate:	38400
Data bits:	8
Stop bits:	2
Parity:	None
Protocol:	Modbus RTU

Figure 1 shows the Fluenta AS Flare Gas Meter (FGM 160) terminals. The only terminals that are of interest in this procedure are terminals 16-20, as they are the terminals that provide a connection to the operator console. There are two possible connections that can be made to these terminals, either a two or four wire RS485 cable. These connections are explained in detail in the following sections.

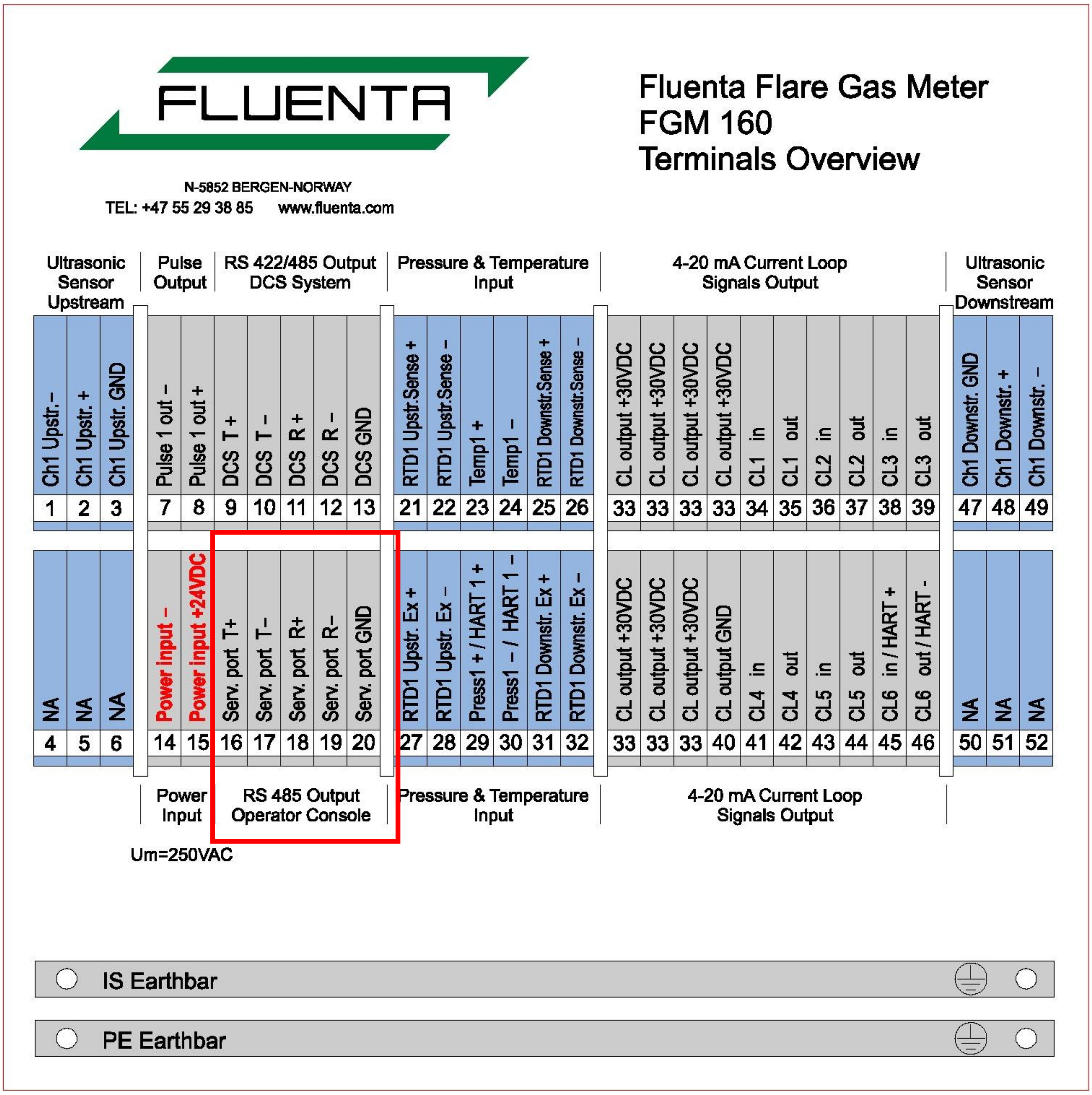


Figure 72 **FGM 160 – Ex-e enclosure connection terminals overview, with RS 485 Operator Console terminals outlined.**

3.1.1 Two-Wire Configuration

In two-wire configuration, the transmit and receive signals share a single pair of wires for half-duplex communications. In fact a third conductor must also interconnect all the devices of the 2W bus: the common conductor.

To avoid conflicts on the communication line, only one driver is allowed to transmit on the line at any time.

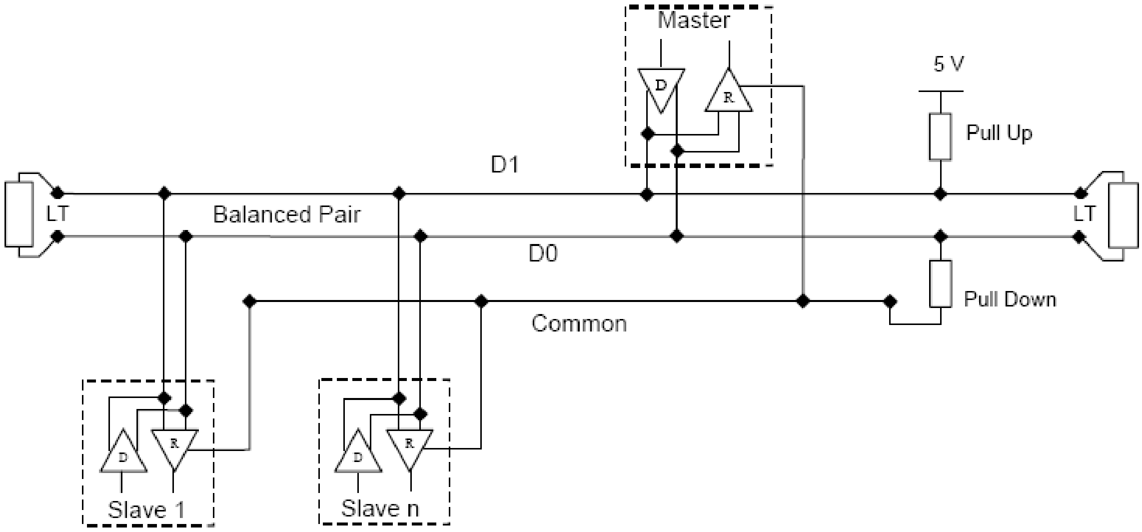


Figure 73 – General 2-Wire Topology.

2-Wire Modbus Circuits Definition:

Signal on Master (O&SC)		EIA/TIA-485 Name	Signal on Slave FGM 160	Description
Name	**Type**			
A(-)	Out/in	A	Serv. Port T- / Serv. Port R-	The line is negative (compared to B) when the line is idle (i.e. data is 1).
B(+)	Out/in	B	Serv. Port T+ / Serv. Port R+	The line is positive (compared to A) when the line is idle (i.e. data is 1).
Common	Common	Signal GND	Serv. Port GND	Common conductor

3.1.2 Four-Wire Configuration

In four-wire configuration, the transmit and receive signals use separate pairs of wires for possible full-duplex communication. In fact a fifth conductor must also interconnect all the devices of the 4W bus: the common conductor.

To avoid conflicts on the communication line in "Multipoint" systems, only one driver is allowed to transmit on the line at any time. "Multipoint" system is defined as system with more than one slave device driver (i.e. systems with one master and two or more slaves).

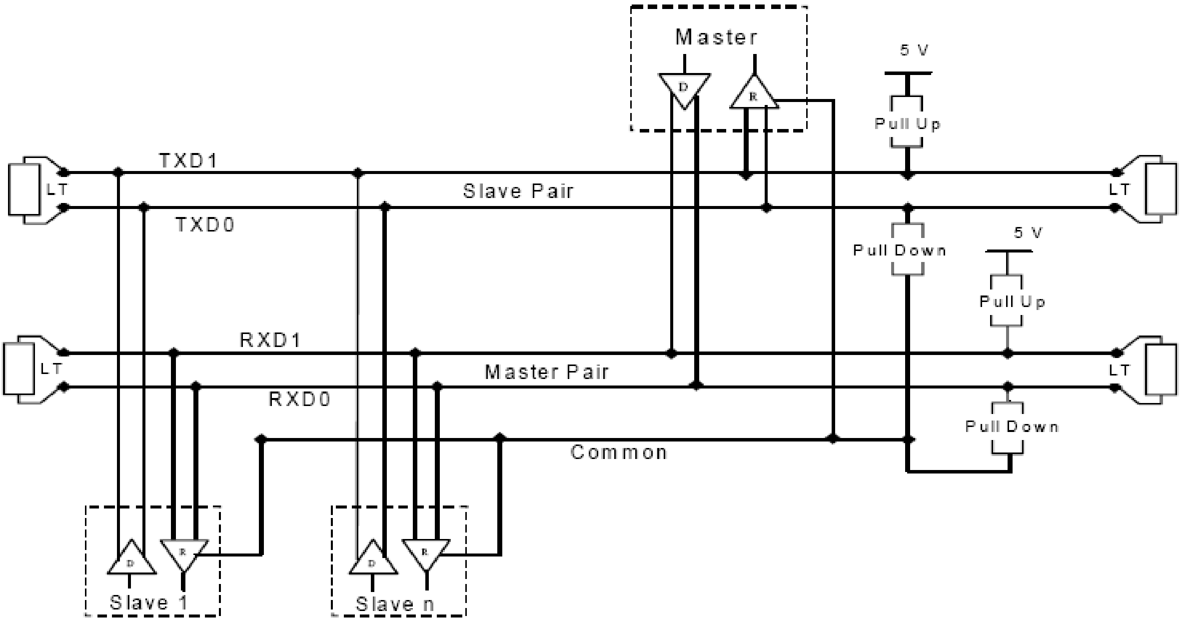


Figure 74 – General 4-Wire Topology.

4-Wire Modbus Circuits Definition:

Signal on Master (O&SC)		EIA/TIA-485 Name	Signal on Slave FGM 160	Description
Name	Type			
T-A(-)	Out	A	Serv. Port R-	The line is negative (compared to B) when the line is idle (i.e. data is 1).
T-B(+)	Out	B	Serv. Port R+	The line is positive (compared to A) when the line is idle (i.e. data is 1).
R-A(-)	In	A’	Serv. Port T-	The line is negative (compared to B’) when the line is idle (i.e. data is 1).
R-B(+)	In	B’	Serv. Port T+	The line is positive (compared to A’) when the line is idle (i.e. data is 1).
Common	Common	Signal GND	Serv. Port GND	Common conductor

The 4-W cabling must cross the two pairs of the bus between the master (O&SC) and the slave (FGM 160). That means that the Tx lines from the master must be connected to the Rx terminals of the slave (FGM 160), and vice versa.

3.1.3 Cable Specifications

The Modbus Serial Line Cable must be shielded. At one end of each cable its shield must be connected to protective ground.

A 2-wire system must use a balanced pair and a third conductor for the Common (signal GND).

An optionally 4-wire system must use two balanced pair and a third conductor for the Common (signal GND).

Wire Gauge:
Wire gauge must be chosen sufficiently wide to permit the chosen combination of baud rate and cable length. AWG24 (0.22 mm^2) is normally sufficient.

Cable length:
The end to end length of the Modbus communication cable must be limited.
The maximum length depends on the baud rate, the cable (Gauge, Capacitance or Characteristic Impedance), the number of loads on the daisy chain, and the network configuration (2-wire or 4-wire).

Grounding:
The "Common" conductor (signal GND) must be connected directly to protective ground, preferably at one point only for the entire bus. Generally this point is close to the master device (DCS system).

Line termination:
Line terminations may be required for high baud rates and long distance.
If line terminations are required, termination resistors should be placed only at the extreme ends of the communication line(s).

The line termination resistors shall be selected according to the cables characteristic impedance; typical 120 Ω. Non-terminated or wrong terminated cables may cause severe communication problems.

Line Polarization:
The FGM 160 does not need any line polarization resistors (pull–up/pull-down resistors).

The RS485 receiver (O&SC) at FGM 160, feature fail-safe circuitry which guarantees a logic-high receiver output when the receiver inputs are open or shorted. This means that the receiver output will be a logic high (passive level) if all transmitters on a transmission line are disabled (high impedance).

3.1.4 RS 485 Connection at FGM 160

The connection below illustrates the 4-wire RS485 connection. Usually either an RS485 to USB or an RS485 to RS232 converter is required to interface to the computer with the Operator & Service Console software installed.

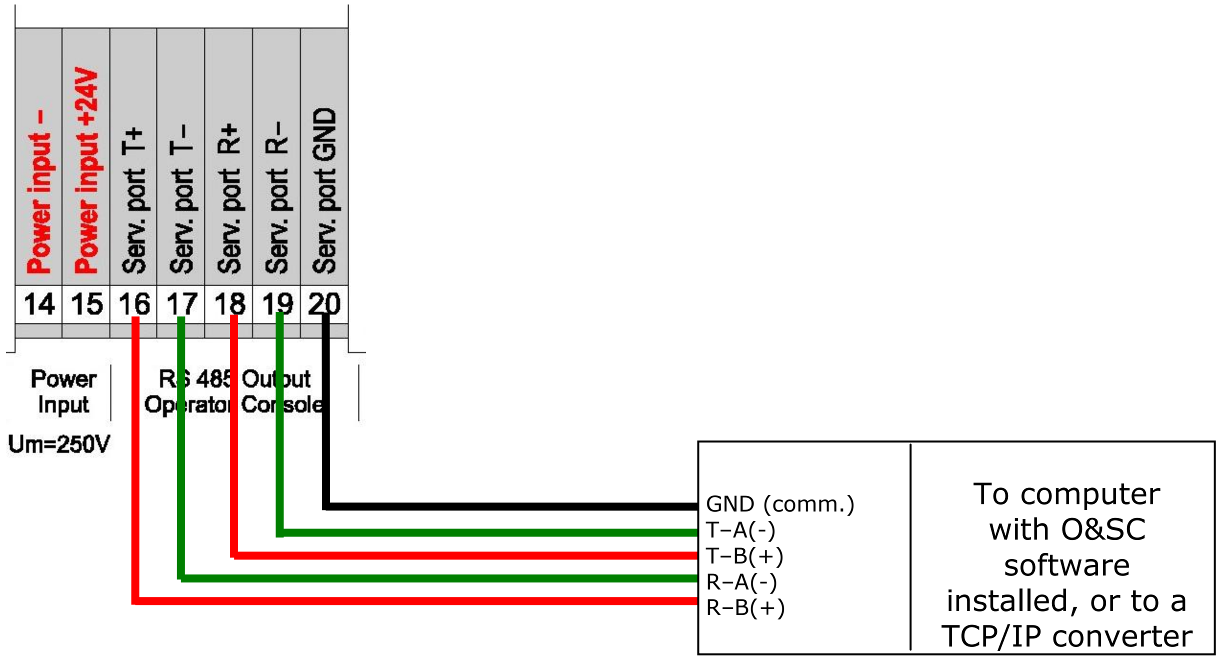


Figure 75 4-wire RS 485 interface between the FGM 160 and the O&SC.

The connection below illustrates the 2-wire RS485 connection. Usually either an RS485 to USB or an RS485 to RS232 converter is required to interface to the computer with the Operator & Service Console software installed.

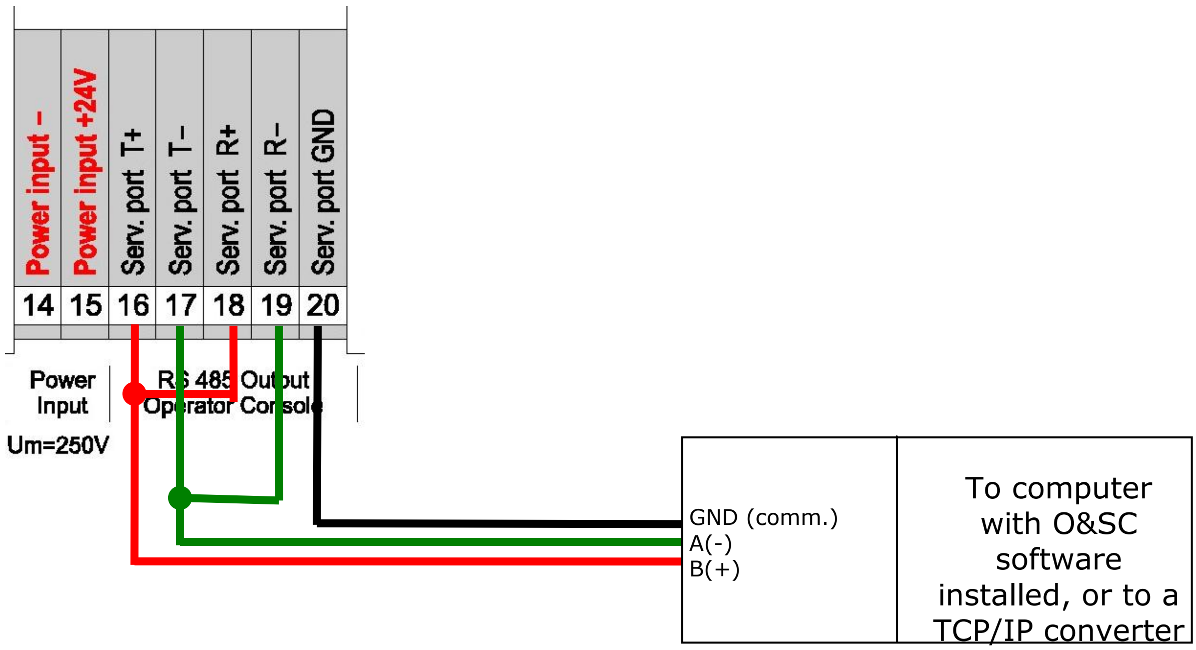


Figure 76 2-wire RS 485 interface between the FGM 160 and the O&SC, with jumpers between T- and R-, and between T+ and R+.

In order to connect FGM 160 to a two-wire physical interface, the following modifications should be done:

- The "Serv. Port - R-" terminal and the "Serv. Port - T-" terminal shall be wired together.
- The "Serv. Port - R+" terminal and the "Serv. Port - T+" terminal shall be wired together.

If remote control of the FGM 160 is requested, a RS485 - TCP/IP converter can be used in order to access the computer with the O&SC software installed.

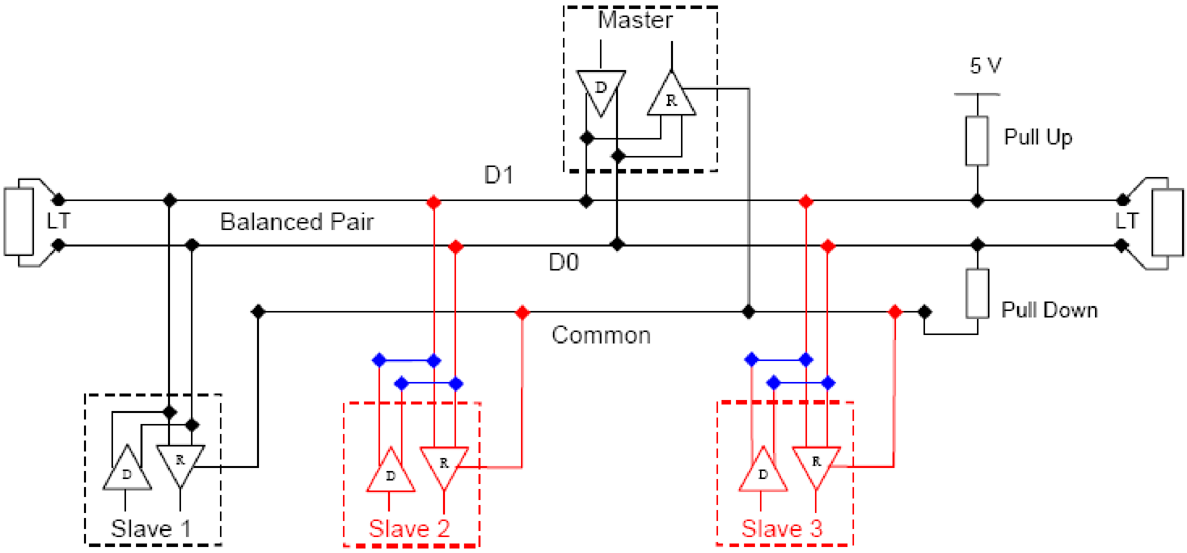


Figure 77 – Connecting devices with 4-Wire interface to a 2-Wire cabling system.

3.2 Remote Operation of the O&SC

The FGM 160 can be remotely operated either through a RS 485 / TCP/IP converter, or through a Remote Control software. The two configurations will both allow for remote operation of the O&SC, but with minor differences:

3.2.1 Remote Operation with RS485 / TCP/IP Converter

Remote operation with RS485 / TCP/IP converter requires the O&SC software to be installed at the remote computer, ref. Figure 78. The operator will access the FGM 160 as if he/she operated the meter locally at site. All functions available in the O&SC are available at the remote computer. If the operator has several O&SC licenses, any of the computers with a valid license and O&SC software can access a specific FGM 160, with a known TCP/IP address.

3.2.2 Remote Operation with Remote Control Software

The Remote Control software allows remote operation of the FGM 160 without the O&SC software installed on more than one computer (at site). A special Remote Control software is installed both at the computer at site (the HOST) and at the remote computer (the GUEST). The remote computer (the GUEST) can not access the local computer (the HOST) unless the HOST grants the GUEST access. Thus, the

operator will have full access control of the HOST computer, allowing only authorized users to access the local (HOST) computer.

By using the Remote Control software, the remote computer (the GUEST) will take control of the local computer (the HOST). Thus, the GUEST will run the O&SC as if the software was installed at the GUEST computer.

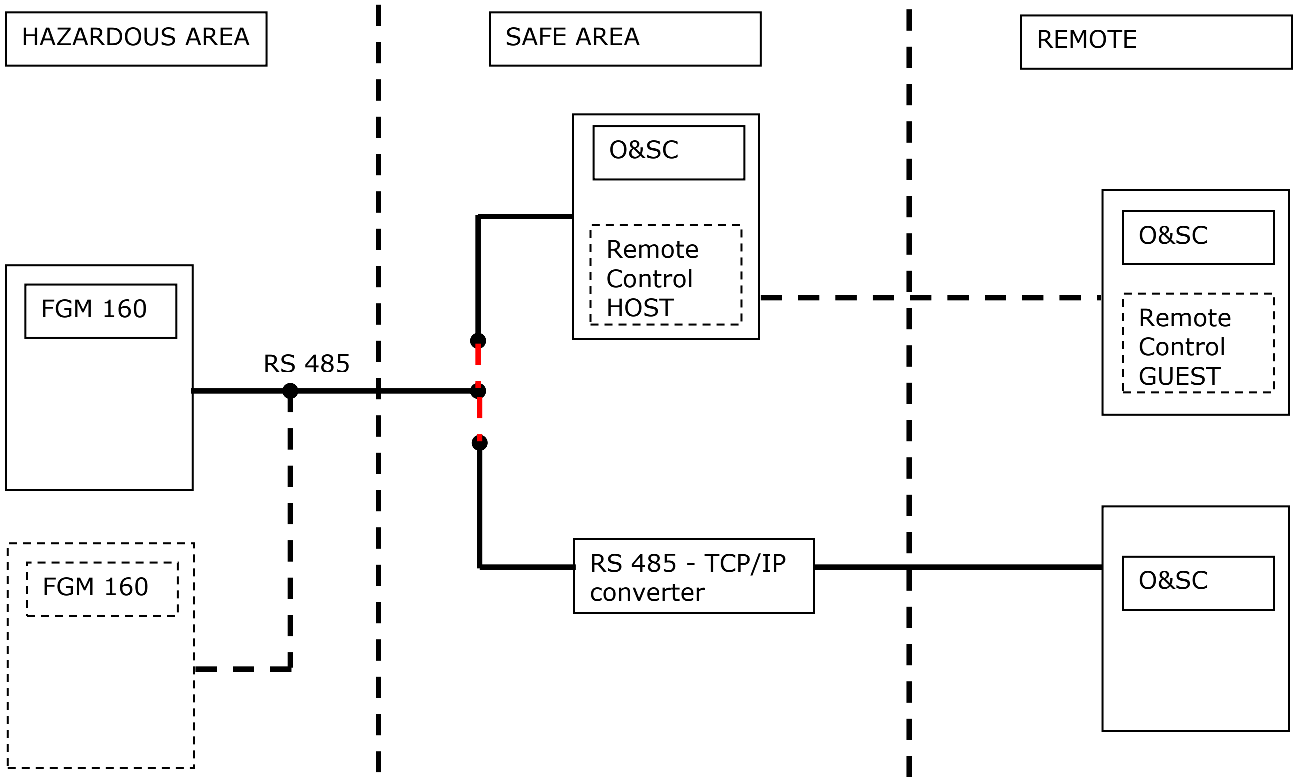


Figure 78 Remote operation of the O&SC, with two different configurations; either by RS485 / TCP/IP interface, or through Remote Control software.

3.3 General Layout

The **Main Window** is shown below in Figure 4. There are several windows that can be displayed in the **Main View Window**, but the three operator windows are shown here. These are the windows that normally are visible when monitoring the meter's operation. The other windows are used for setup and formatting functions. These three windows can be accessed via the **View** menu, and are the **Graph Bar**, **Live Data** and **Log** windows. By double clicking on the windows heading bar it is possible to un-dock it from the main window, dragging it back into the main window's view area will re-dock it.

To avoid docking a window, hold the Ctrl-key down while dragging.

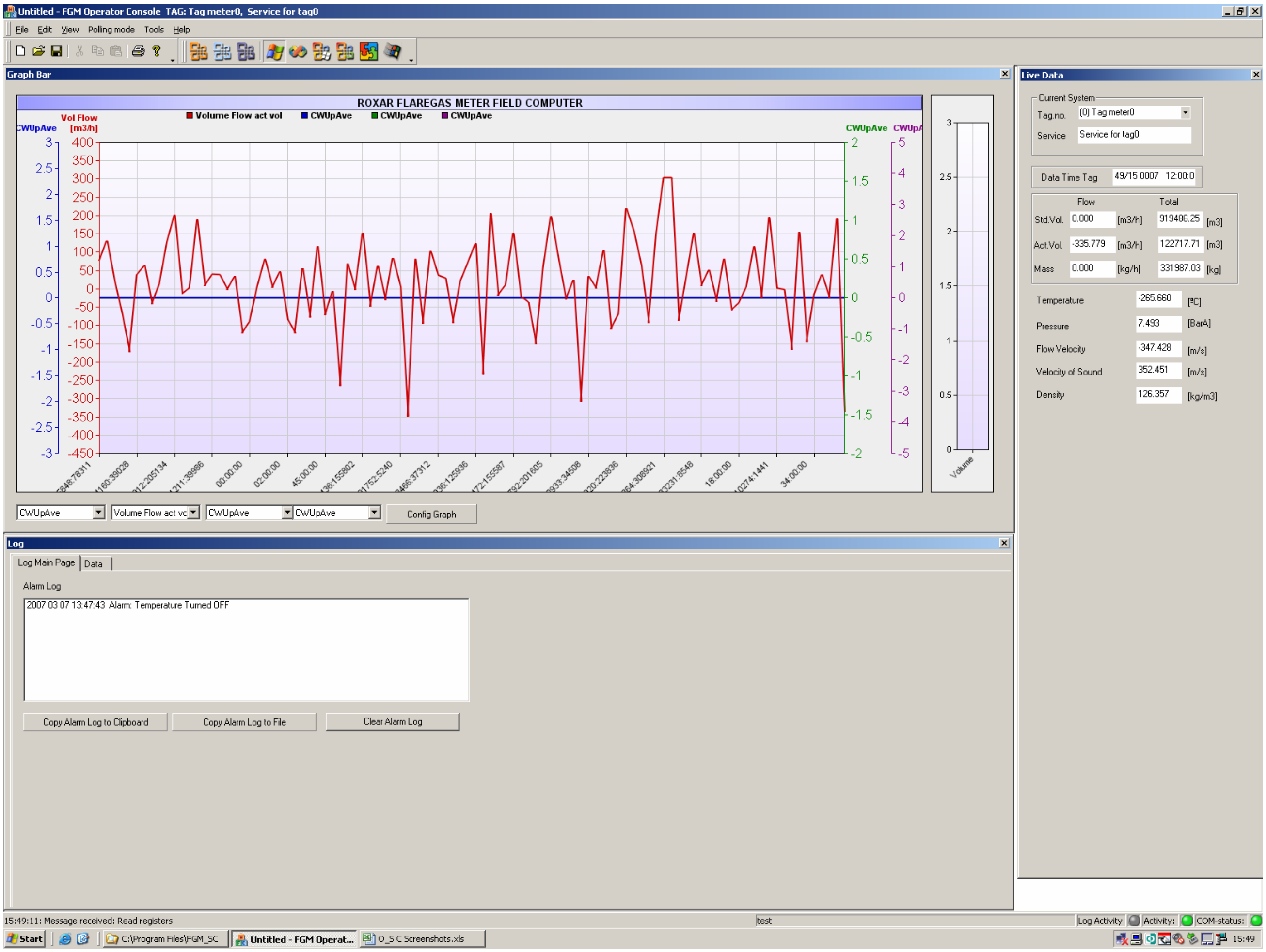


Figure 79 O&SC general layout, with Graph Bar, Live Data and Log windows.

3.3.1 O&SC Menus

The O&SC menus are displayed below. The menu items shown below will be covered in this document. The icons in the bottom menu bar allow the user to change the appearance of the program.

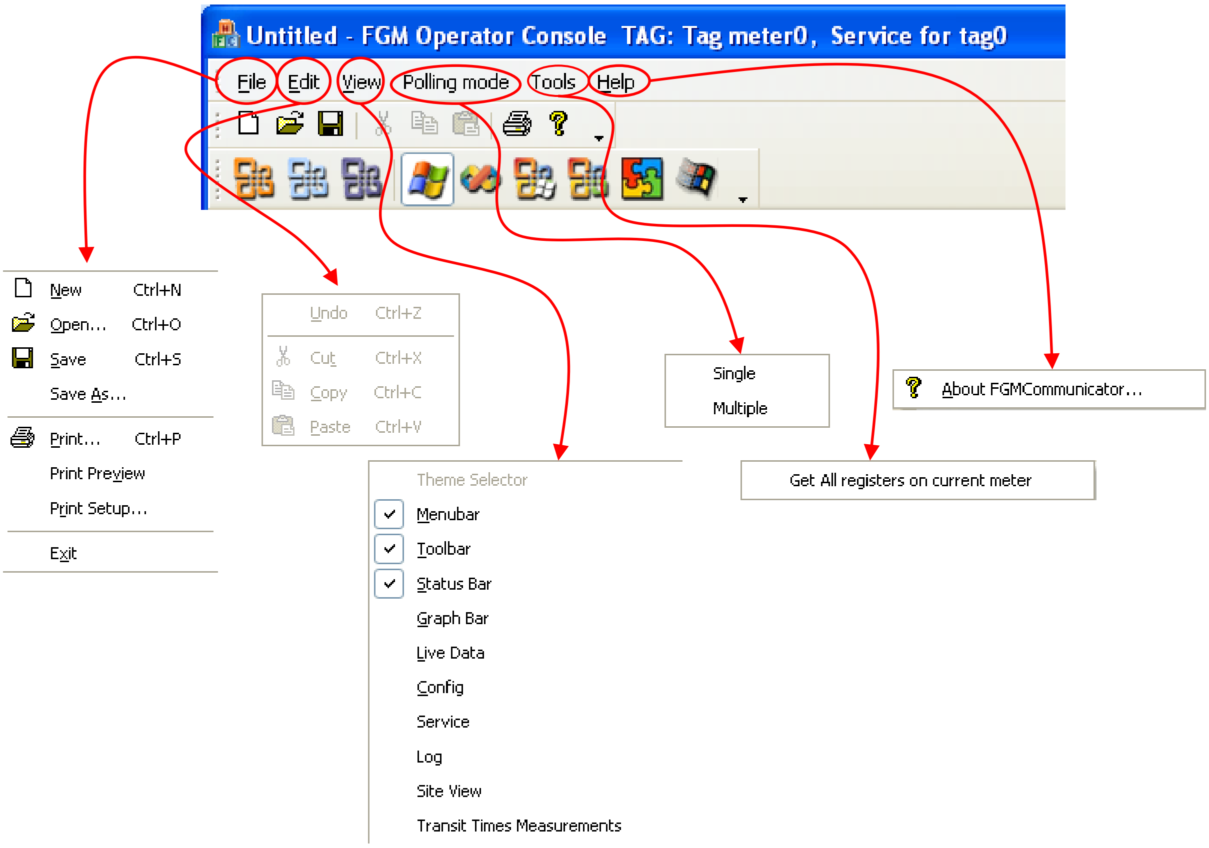


Figure 80 The O&SC menus overview, with the "File", "Edit", "View", "Polling mode", "Tools" and "Help" items outlined.

3.4 Live Data Window

The **Live Data** window can be activated by choosing the **View** → **Live Data** pop-up menu from the main window. The **Live Data** window shows the *Current System* data, along with the volume and mass flow rates. Further, totalized values for volume and mass are displayed. These values are non-resetable, and display the total values since the system was put in operation. The temperature, pressure, flow velocity, velocity of sound, and density are also presented in this window. The *Data Time Tag* is the actual time the present displayed data set was measured or calculated.

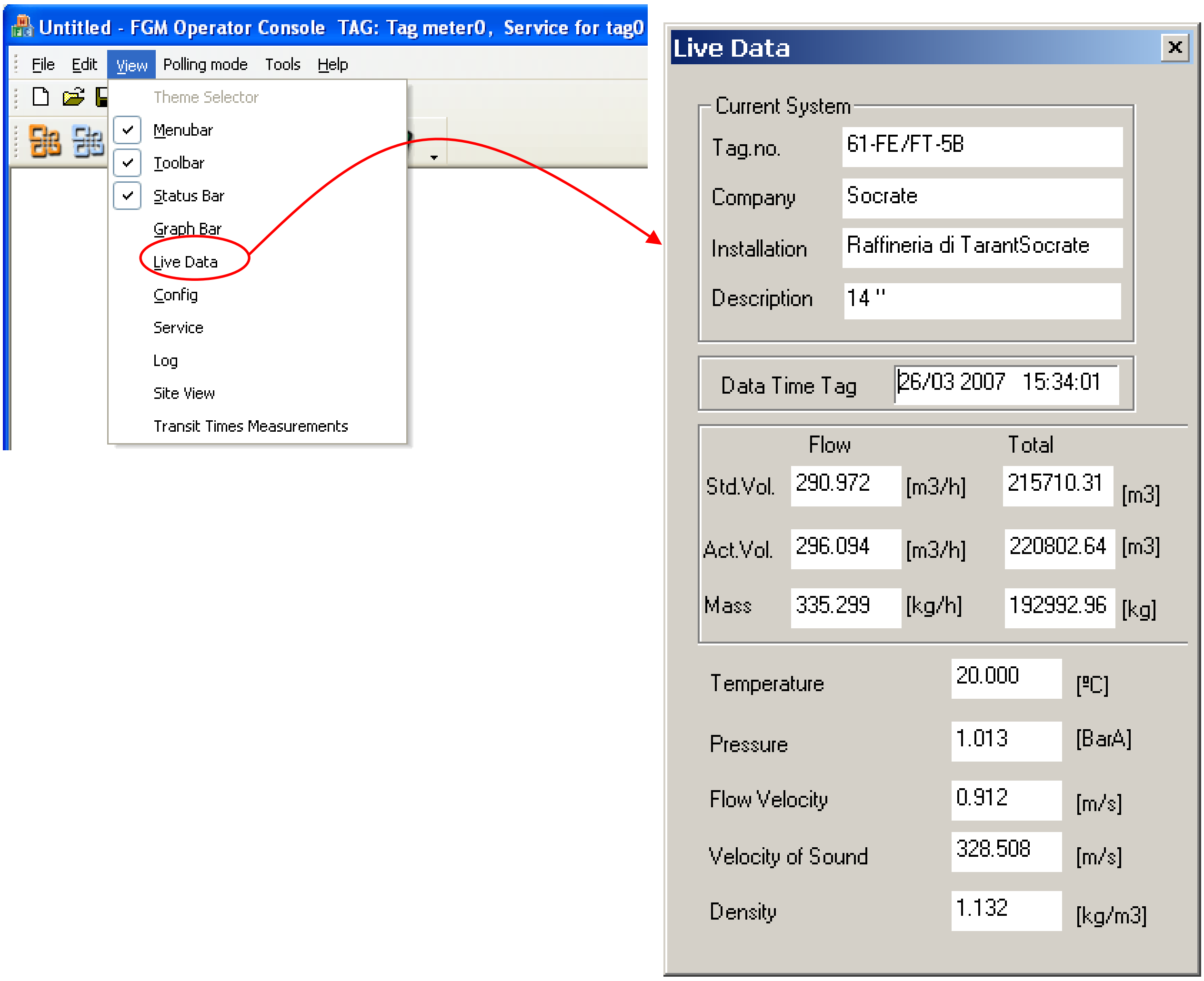


Figure 81 **The Live Data window is activated through the View → Live data menu. The Live Data window is a read-only information window, with information on the current system and updated (live) process data.**

3.5 Graph Bar Window

The **Graph Bar** window displays up to four different parameters as graph data. Thus, the operator can view selected parameters as trend data for easy monitoring of process variations. The graph parameters can be selected from:

- Mass Flow
- Volume Flow act vol – The volume flow at actual (line) conditions
- Volume Flow std vol – The volume flow at standard conditions
- Gas Flow Velocity
- Pressure
- Temperature
- Density
- Sound Velocity
- CWUpAve – Average transit time in the Upstream direction

- CWDownAve – Average transit time in the Downstream direction
- Unused

If it is desired to have less than four parameters shown on the graph, select the "Unused" option. The legend at the top of the **Graph Bar** window shows which items are currently being displayed.

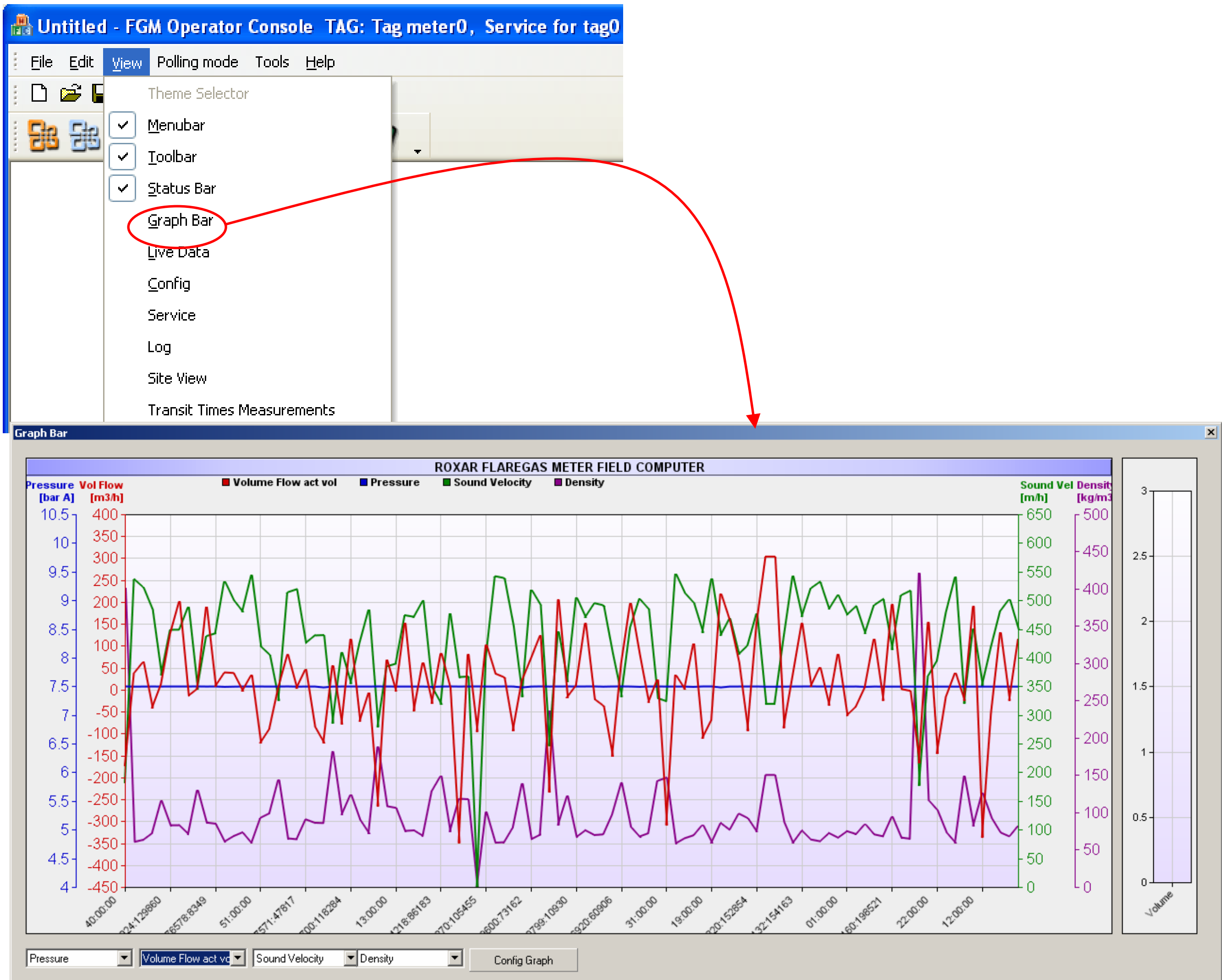


Figure 82 **The Graph Bar window, with up to four different process parameters displayed as graph data.**

3.5.1 Graph Config Window

By pressing the Config Graph button the **Graph Config** window opens. This allows the operator to configure the look of the graph as well as the scale. The trend diagram area allows the operator to choose the Y Scale and the Time Scale. The Y Scale can either be set to automatic by checking the checkbox next to the field Autoscale and setting the minimum range, or stated explicitly by entering the minimum and maximum values for the parameters. The **Bar Plot** area allows the operator to set the maximum value, the warning, and whether to plot Mass Flow or Volume Flow.

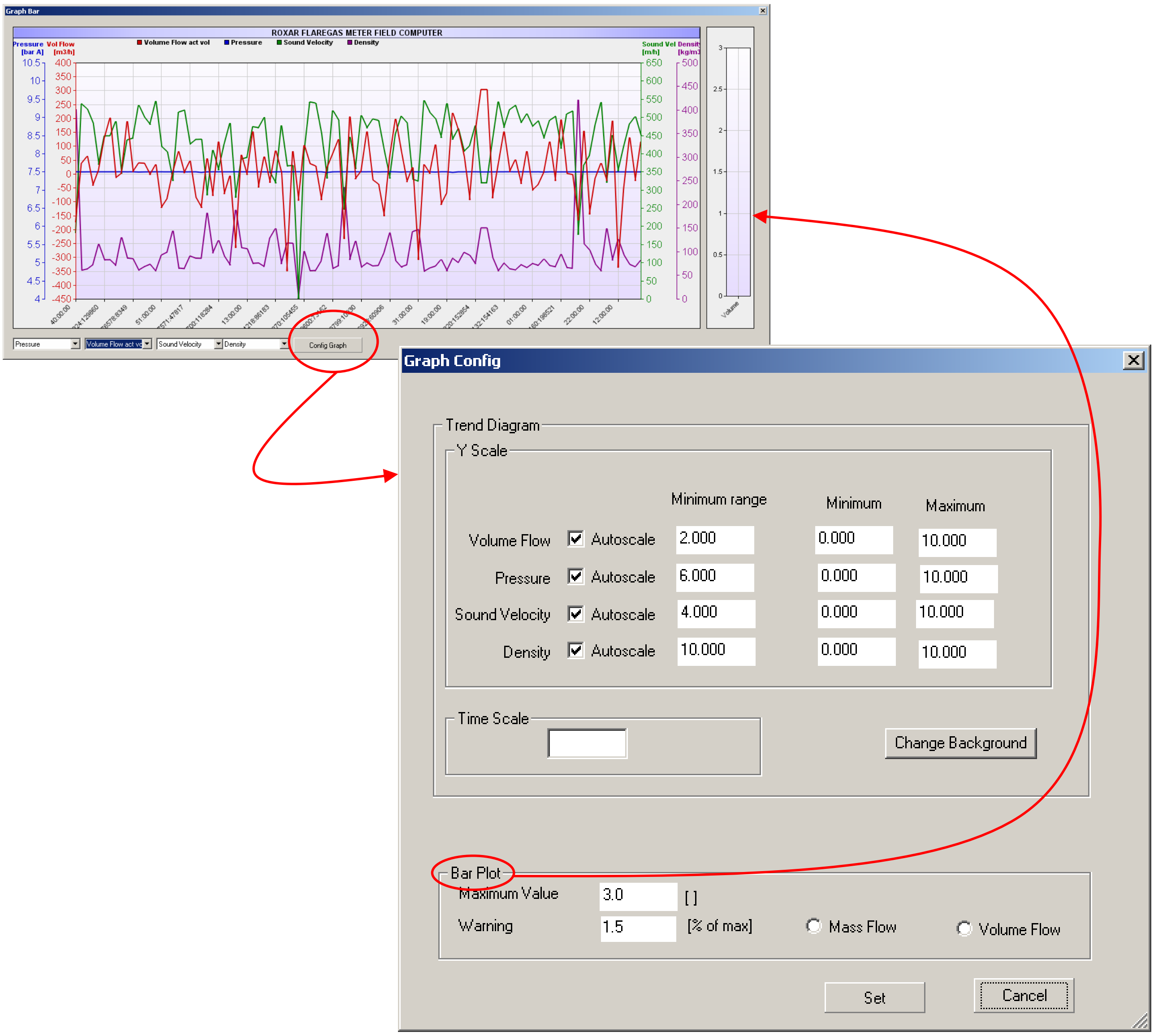


Figure 83 **The Graph Bar - Graph Config window. Each graph bar can be individually configured with either autoscale or defined minimum and maximum range. If autoscale is selected, a minimum range (span) can be set.**

3.6 Log

3.6.1 Alarm Log

By selecting the **Log** option from the **View** menu item from the **Main Window**. The window comes up showing the **Log Main Page** tab which lists the alarms that have occurred. There are two options when it comes to copying the **Alarm Log**. The first is to copy it to the clipboard. This enables the operator to paste the data wherever necessary. The second is to copy the alarm log to a file. This saves the **Alarm Log** as a text file to a specified location. The last choice in this tab is to clear the alarm log.

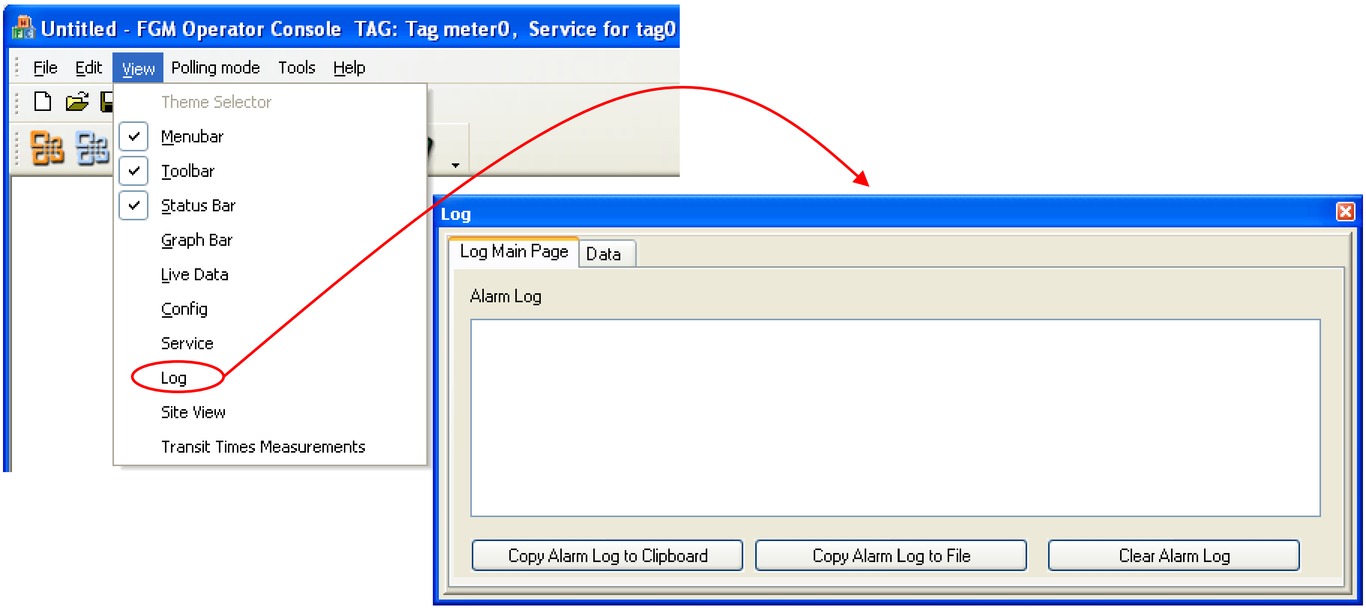


Figure 84 The Log – Log Main Page window.

3.6.2 Log Data

The **Data** tab in the **Log** window displays the options for what kind of data is logged. Checking the **Log Measured Data** checkbox enables data logging, and the **Optional sub** category allows the operator to specify a sub-directory to where the data log file will be saved. The button Set All allows the operator to log all of the parameters that are available below. The **Clear All** button unselects all of the options below. This is useful when only a few options are desired. The **Set Default** button sets a default set of parameters to be logged. It is possible to check or uncheck any of the parameters that are listed.

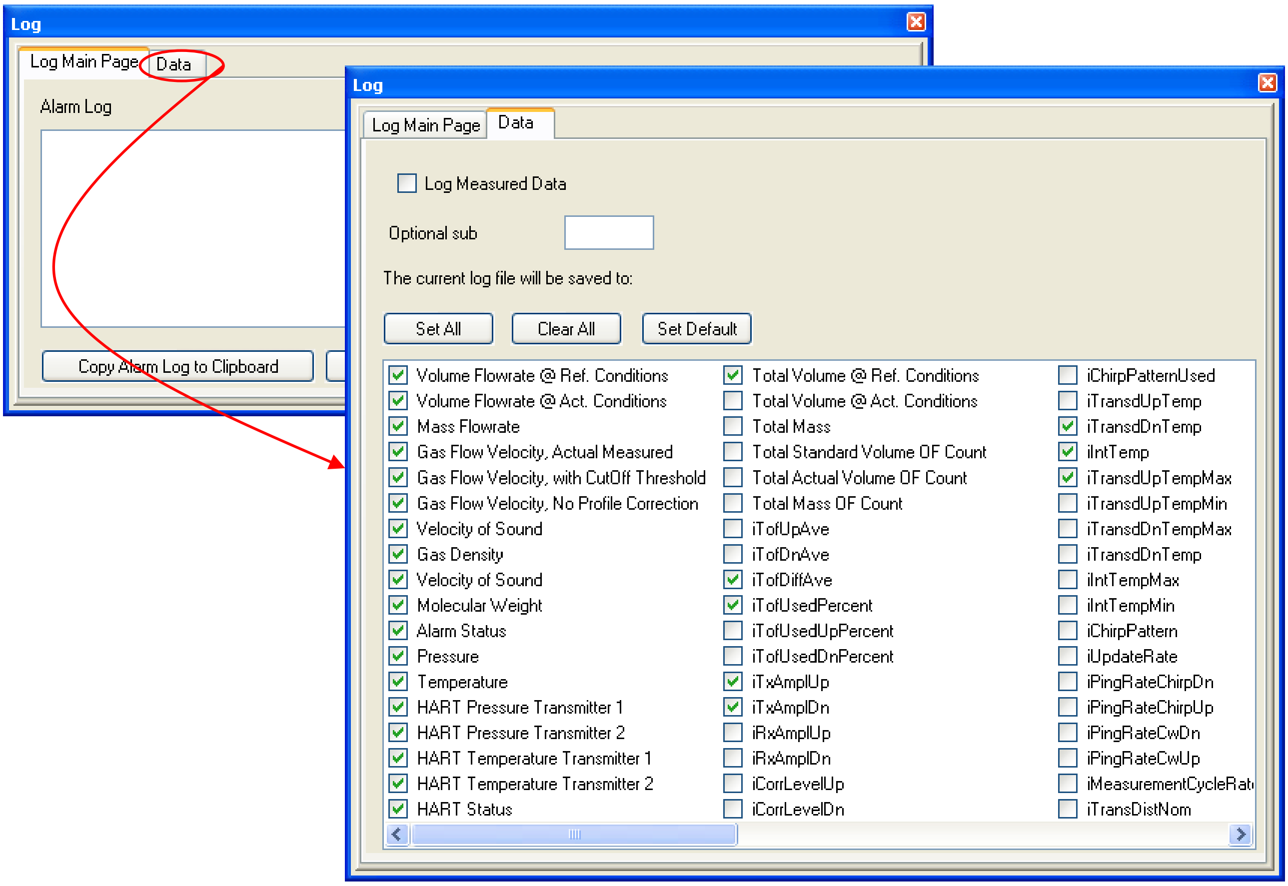


Figure 85 The Log - Data window.

3.7 Config Window

3.7.1 Config Main Page

The **Config Main Page** tab comes up automatically when choosing the **View** → **Config** menu item. The **System Configuration** section allows the operator to insert a serial number, specify the system version (Single Ch1, Single Ch2, Dual Path and Double), as well as insert the start time for the 24 hours Accumulated values.

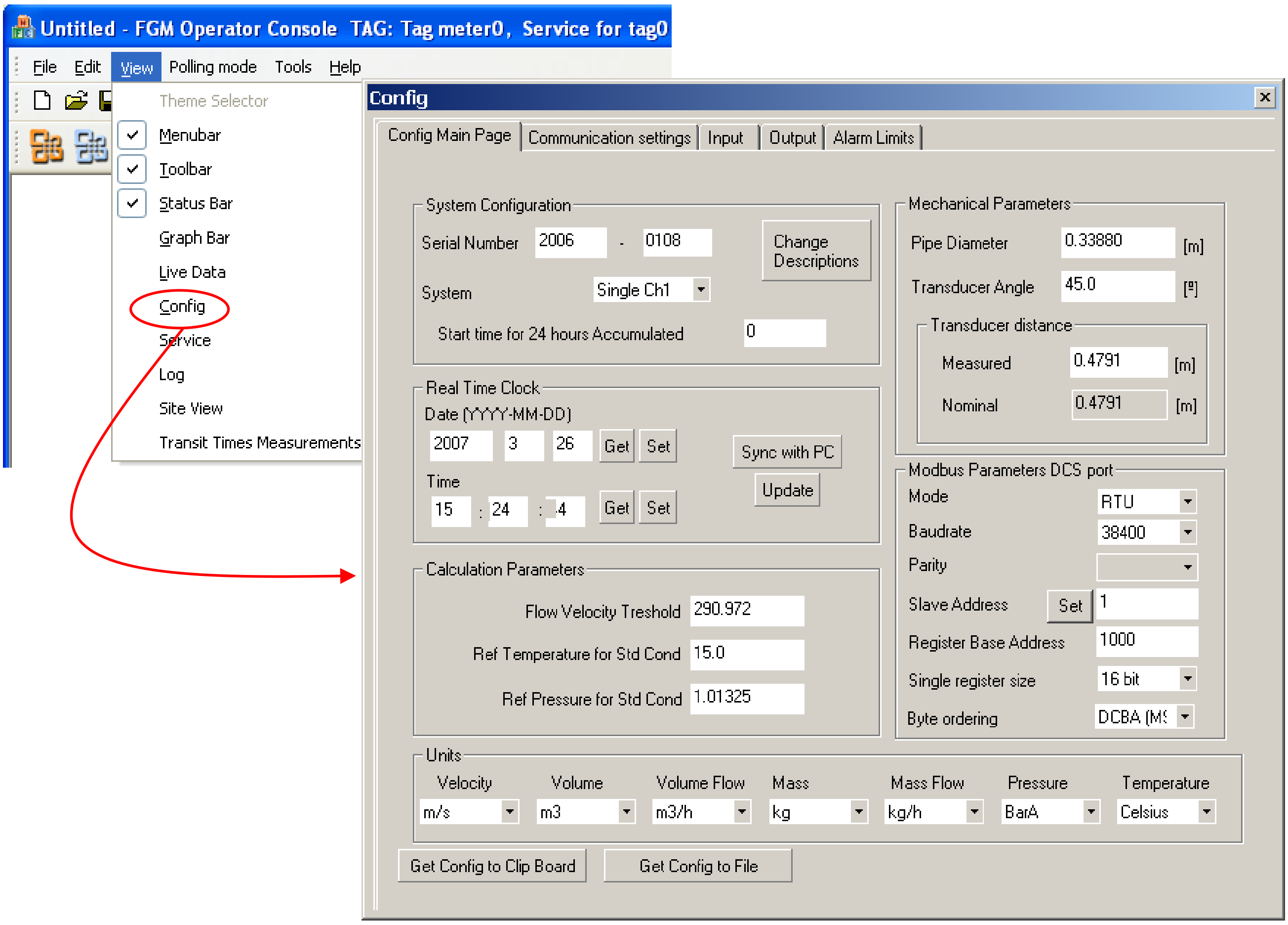


Figure 86 The Config – Config Main Page window

The **Change Descriptions** button opens the **System Description** dialog box, ref. Figure 87. This allows the operator to change the information shown in the **Live Data** window shown in Section 3.4.

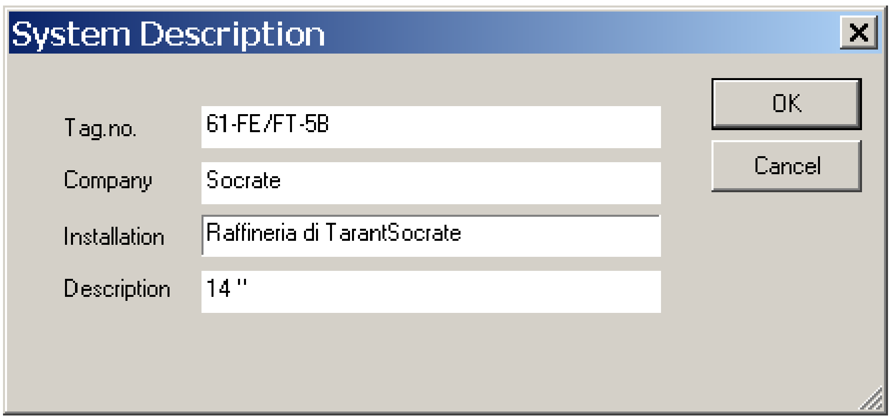


Figure 87 The Config – Config Main Page – Change Description window.

The **Real Time Clock** section allows the operator to set or get the clock readings from the flow computer. The **Synch with PC** button synchronizes the flow computer clock with the clock in the PC running the Operator and Service Console software.

The **Update** button updates (refreshes) the real time clock values based on current information locally on the O&SC computer. The **Calculation Parameters** section allows the operator to set the **Flow Velocity Threshold (cut-off)**, the reference temperature for standard conditions, and the reference pressure for standard conditions. The flow velocity threshold is the low flow cut-off limit that can be implemented upon operator request. Flow values below the cut-off limit will be set to zero. The reference temperature for standard conditions is default 15.0 °C, and the reference pressure for standard conditions is default 1.01325 barA.

The Units section allows the operator to switch from SI units to English units. This changes the units for the DCS Modbus and HART register values.

The **Mechanical Parameters** section makes it possible to change the physical parameters of the installation. This should only be necessary during installation and hook-up.

The Modbus Parameters DCS port section allows the operator to set up the communication parameters.

The **Get Config to Clip Board** copies the configurations file to the clip board so that it can be pasted into an existing document (e.g. configuration file template). The button **Get Config to File** saves the system configuration to a text file. The dialog boxes in Figure 88 illustrate how this is done.

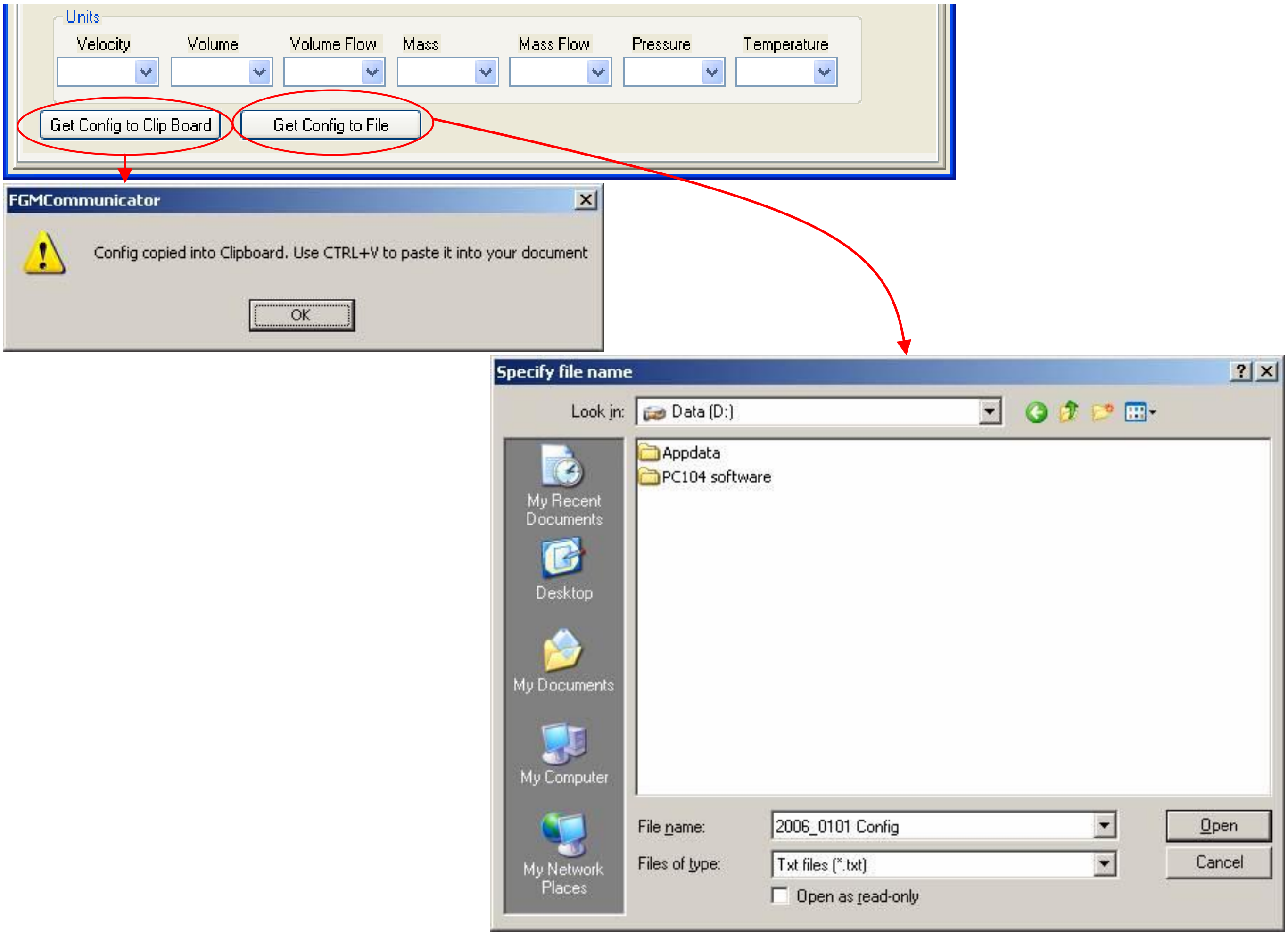


Figure 88 Copying system configuration to the clipboard and saving to a file.

3.7.2 Communication Settings

In the communication setting tab in the **Config Main Page** the operator can set up the Modbus interface on the PC. The Com port can be selected. The Timeout value for the com port can be altered (Should normally not be altered). And finally the operator can select the Modbus address. This allows the operator to select to operate one specific instrument, if multidrop is not used; the slave address should always be 1.

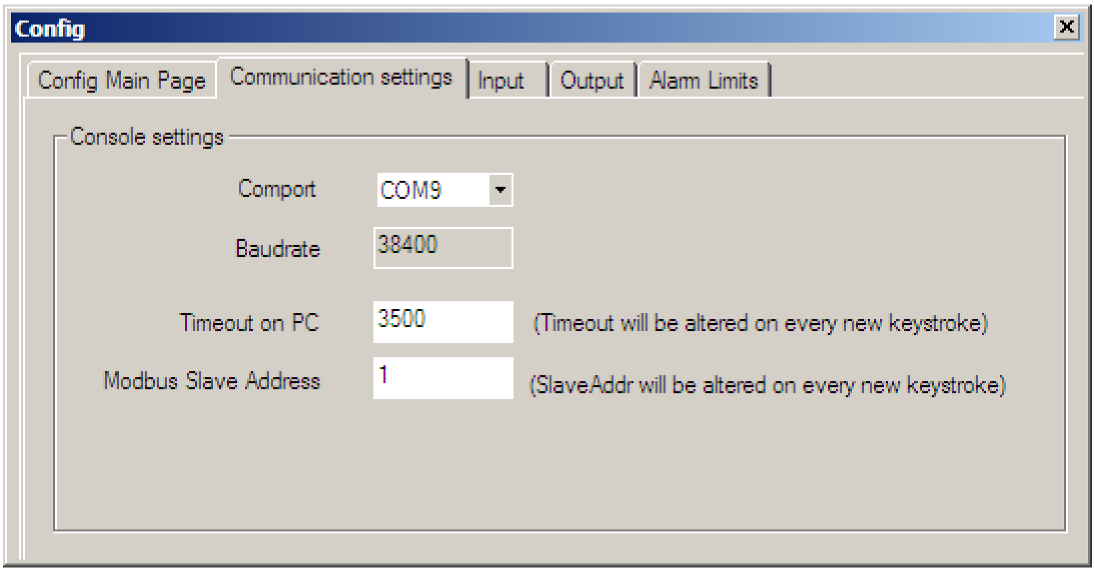


Figure 89 The Config - Communication settings window.

3.7.3 Input Signal Configuration

The **Input** signal configuration window shown in Figure 90 allows the operator to configure the Pressure and Temperature input signals to the meter.

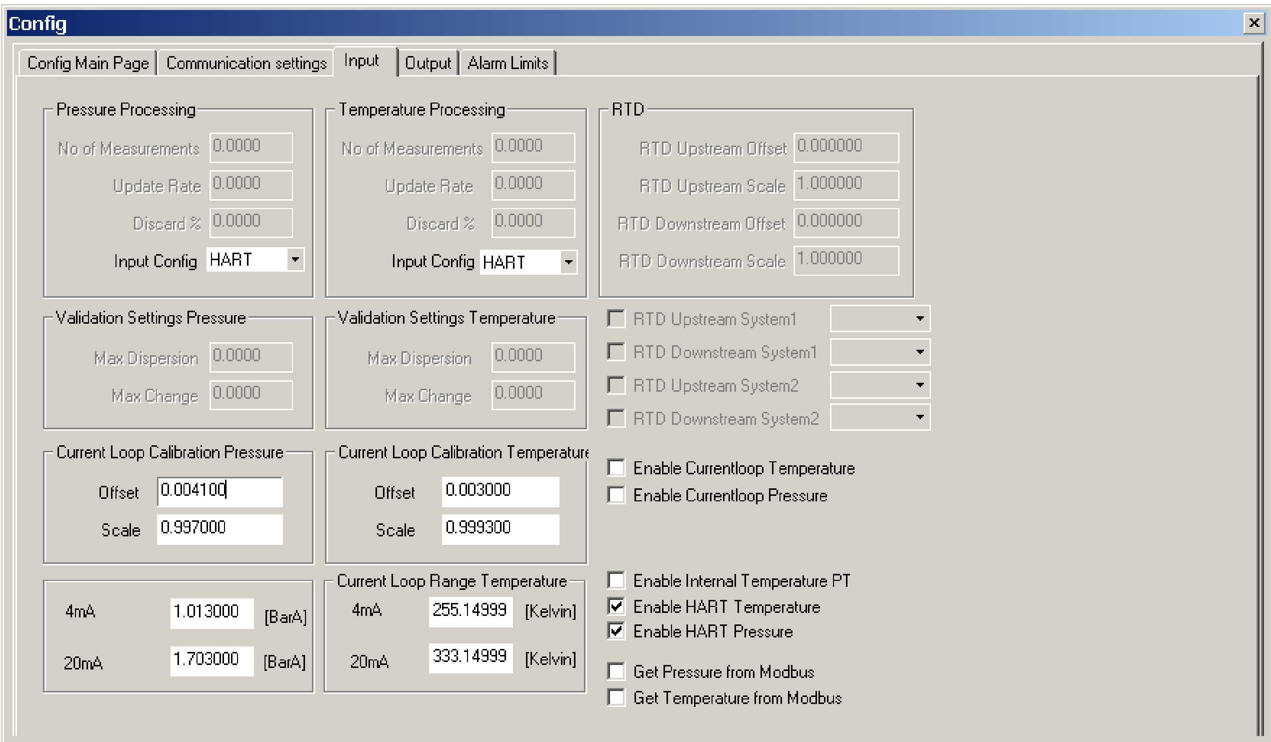


Figure 90 The Config - Input signals configuration window, with HART interface selected for the pressure and temperature input signals.

The Pressure Processing drop down selection box allows the user to switch between the HART and the Current Loop as sources for the pressure input.

The Temperature Processing drop down selection box allows the user to switch between the HART, Current Loop, and RTD as sources for temperature input. The RTD is integrated in the ultrasonic sensors, and will measure the process temperature through the ultrasonic sensor walls (RTD is usually not used for input into process measurement).

The *Current Loop Calibration Pressure* and *Temperature* groups allow the operator to set the offset and scale for the pressure and temperature inputs, ref. Figure 91.

When selecting the HART interface for the pressure and temperature input signals, the *Input Config* must be set to HART. Further the check boxes *Enable HART Temperature/Pressure* must be selected (checked), ref. Figure 90.

When selecting the 4-20 mA current loop interface for the pressure and temperature input signals, the check boxes for *Enable CurrentLoop Temperature/Pressure* must also be selected (checked), ref. Figure 91. *Enable HART Temperature/Pressure* should NOT be checked in this case.

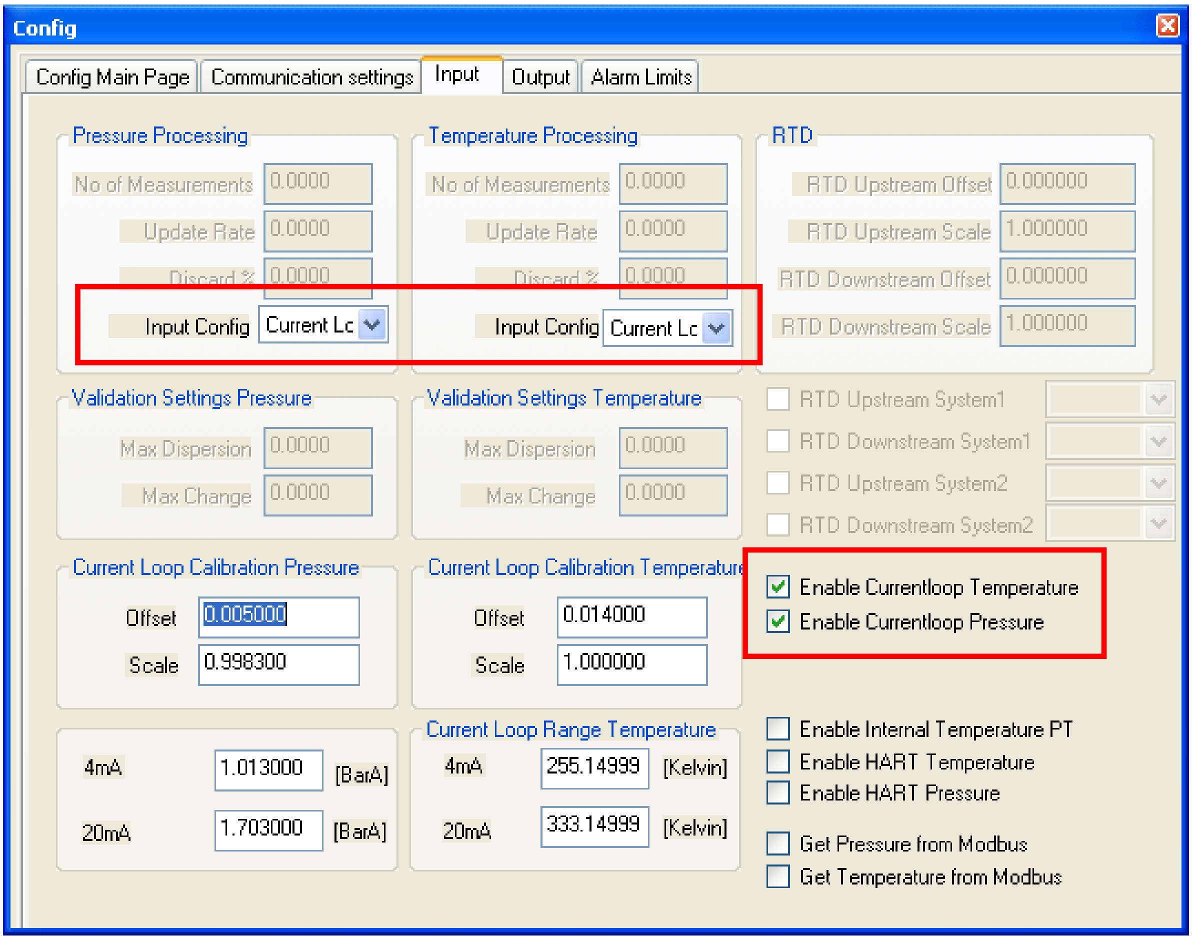


Figure 91 The Config - Input signals configuration window, with 4-20 mA current loop interface selected for the pressure and temperature input signals.

The *Current Loop Range: Temperature & Pressure* groups allow the operator to set the 4-20mA range to the corresponding temperatures and pressures, respectively. It is important that these ranges match the output ranges of the transmitters. If not, the readings of the FGM 160 will not be correct. If HART interface is selected, the settings for *Current Loop Range: Temperature & Pressure* will have no effect, as the pressure and temperature values will be transmitted as digital values.

The 4-20 mA input channels can be calibrated using e.g. a loop calibrator. By using a first degree curve fitting approach, the offset and scale values can be obtained. The 4-20 mA input channels of the FGM 160 are calibrated at the Fluenta AS workshop, ensuring that no calibration should be required during installation and commissioning, ref. Figure 91.

If no direct interface from the pressure and temperature transmitters has been established, these process values can be transmitted from the DCS system to the FGM 160 through the DCS Modbus interface. The DCS system must then, as Modbus master, supply pressure and temperature values to the FGM 160 at regular intervals. In order to enable the FGM 160 to read pressure and temperature values through the DCS Modbus interface, the *Get Pressure/Temperature from Modbus* check boxes must be selected (checked), ref. Figure 92.

Note: The check boxes are NOT exclusive. Thus, selecting one check box does not automatically deselect the alternative option check box. Make sure that options that are not selected, are deselected (NOT checked).

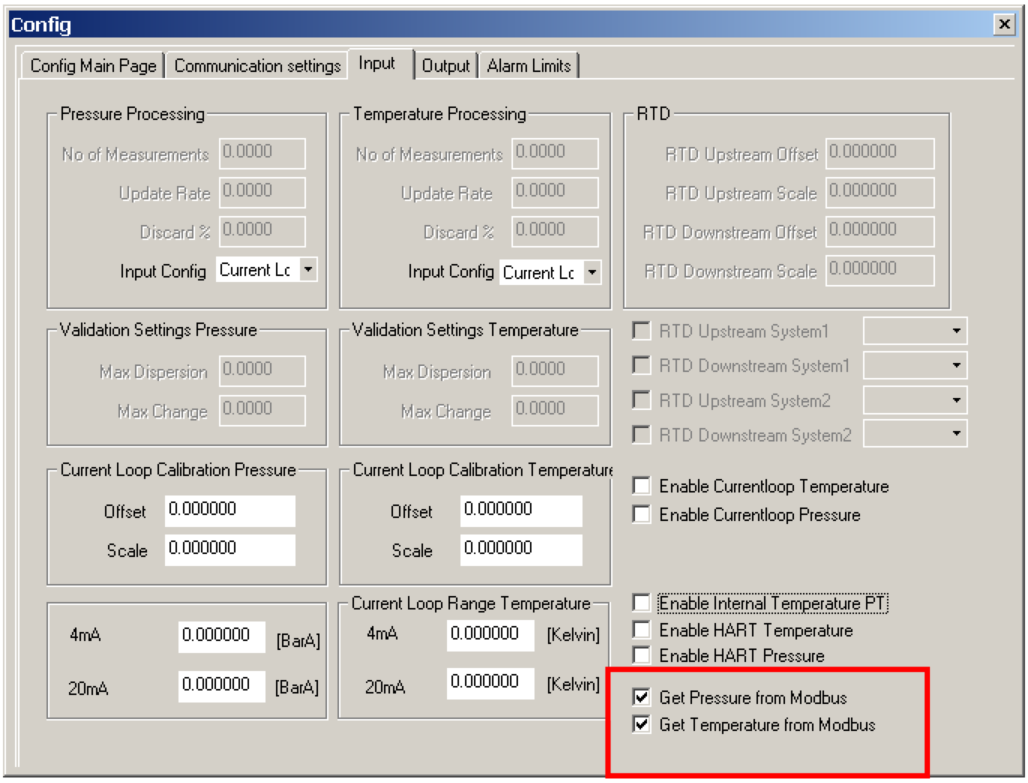


Figure 92 The Config - Input signals configuration window, with DCS Modbus interface selected for the pressure and temperature input signals.

3.7.4 Output Signal Configuration

The **Config - Output** window allows the operator to configure the output from the flow computer. The group of check boxes labeled *Output Enable* determines which output is to be used, ref. Figure 93.

For each of the current loops enabled, the corresponding *Current loop X* (*X* being the number of the current loop 1- 6) must be configured. The drop down box allows the user to select which parameter will be transmitted at the output. The choices are Std. Volume flow, Actual Volume flow, Mass flow, Density, Molecular weight, Alarm, Temperature, Pressure, and Testvalue, ref. Figure 94. The desired parameter must be selected and the corresponding configuration values to the right must be entered.

If the *Enable HART* check box is selected, the *HART Output (Slave) Config* group must be configured, ref. Figure 93. The Poll address must be entered, and up to four parameters can be selected. These parameters can be any combination of Flow Std, Flow Act, Flow Mass, Flow Velocity, Sound Velocity, Density, Pressure and Temperature.

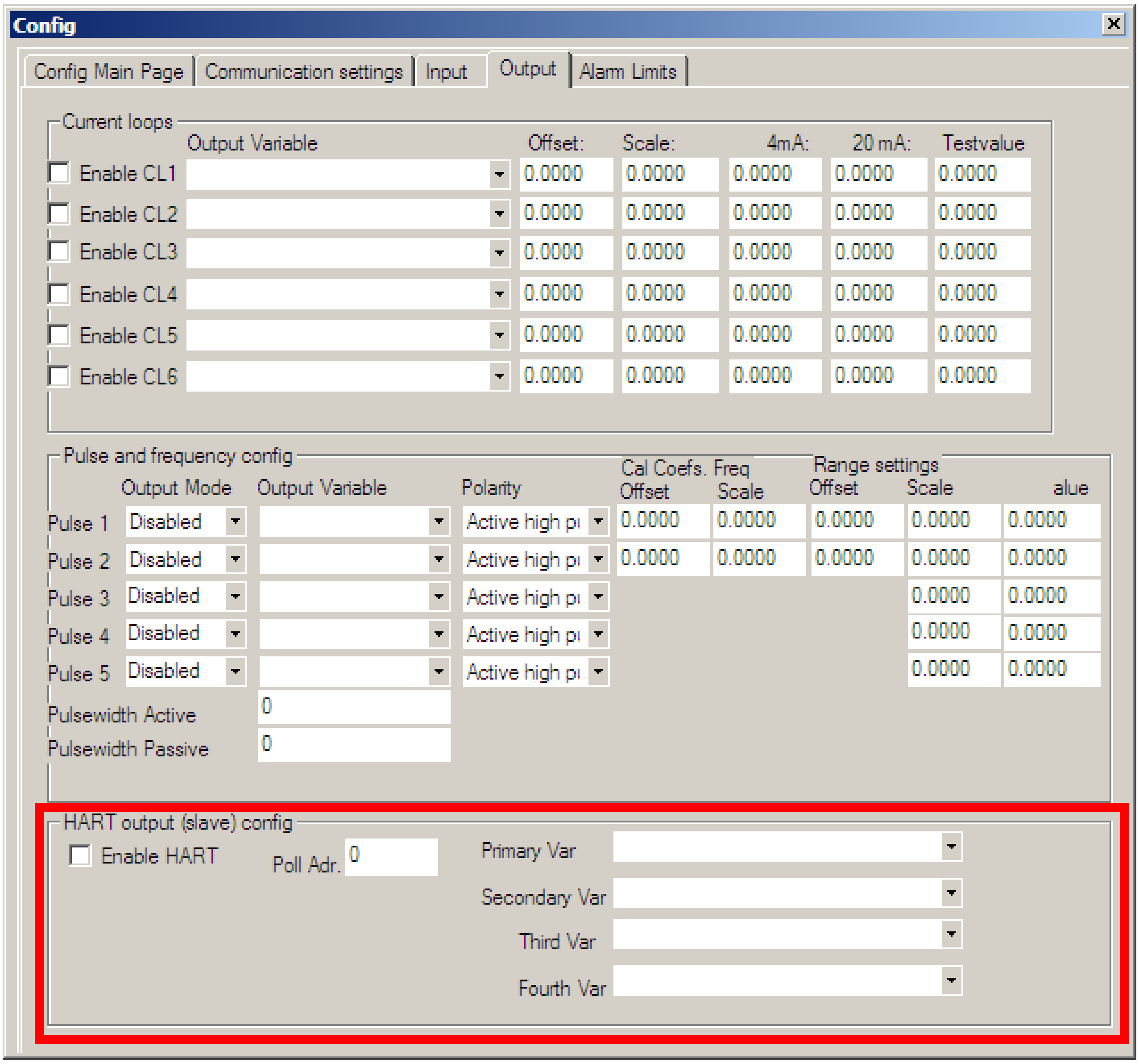


Figure 93 The Config - Output signal configuration window, with the HART Output (Slave) Config box outlined. The Poll Address must be selected (1 – 15), and up to four predefined process parameters can be selected at the HART output.

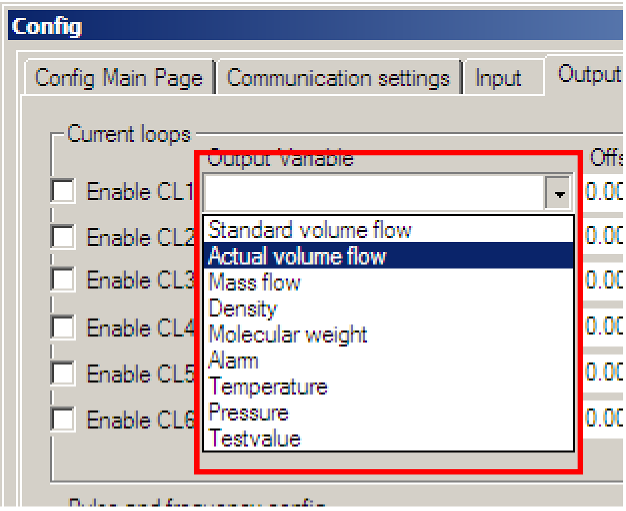


Figure 94 The Config - Output signal configuration window, with the parameters available at the 4-20 mA current loop outputs outlined.

3.7.5 Alarm Limits Configuration

The **Alarm Limits** tab in the **Config** window allows the operator to configure the alarm settings.

The *Sound Velocity* has four parameters that must be specified:

1. The Maximum and Minimum which are the upper and lower limits of the sound velocity before an alarm is generated.
2. The Maximum Sound Velocity jump regarded as an expected process variation.
3. The Historical VOS weight factor which is used in calculating the Historical VOS.

The *Flow Velocity* has three parameters that must be specified:

1. The Maximum and Minimum which are the upper and lower limits of the flow velocity before an alarm is generated.
2. The Maximum Change which is the maximum difference between two consecutive readings before an error is reported.

For the *Temperature* and *Pressure*, the Maximum and Minimum alarm values must be specified. Input values outside the alarm range will generate an alarm.

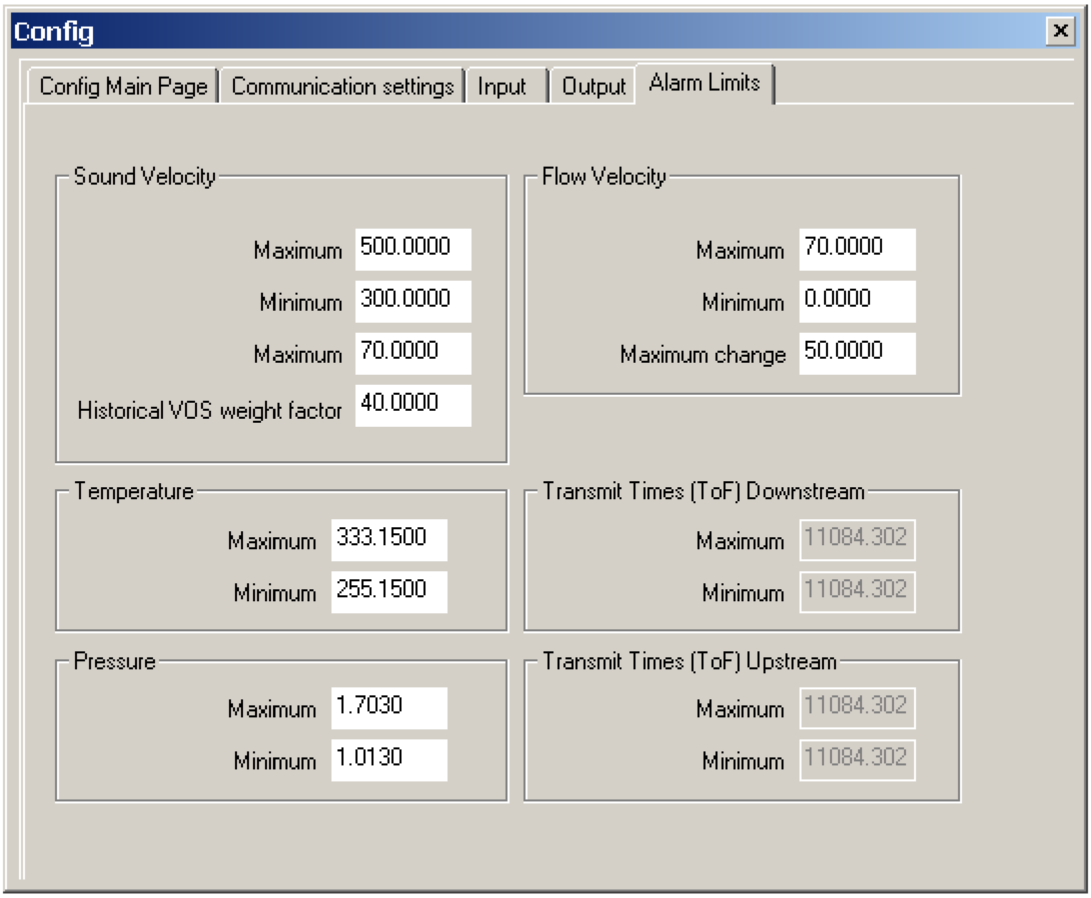


Figure 95 The Config - Alarm Limits window, with specified Maximum and Minimum values for Sound Velocity, Flow Velocity, Temperature and Pressure.

Based on the specified transducer distance and the max/min values for Sound Velocity and Flow Velocity, the Maximum and Minimum values for Time-of-Flight (TOF) Downstream and Upstream are calculated. These values are used internally in the FGM 160 in order to check the validity of the transit time measurements.

3.8 Transit Time Measurements Window

The **Transit Time Measurements** Window can be accessed via the **View** → **Transit Times Measurements** menu item. This window allows the operator to view the measured transit times, both the Chirp transit times, the CW period fraction measurements, and the (Chirp and CW) combined transit times that are used for the flow calculations. The CW period fraction value is a counter value corresponding to the fraction of a CW period, a number between 0 and 15000 (typical), dependent on CW signal frequency.

Further, the % used of the measured transit times for the flow calculations are displayed. If all measured transit times are used for the flow calculations, the numbers should be 100.0. Any erroneous measurements or outliers that are discarded during the filtering process will reduce the number of % used.

In addition, the gas flow velocities can be viewed, both prior to flow profile compensation (uncompensated) and after flow profile compensation. Thus, the "raw" (uncompensated) axial gas flow velocity can be viewed, along with the *average* axial gas flow velocity (compensated for flow profile).

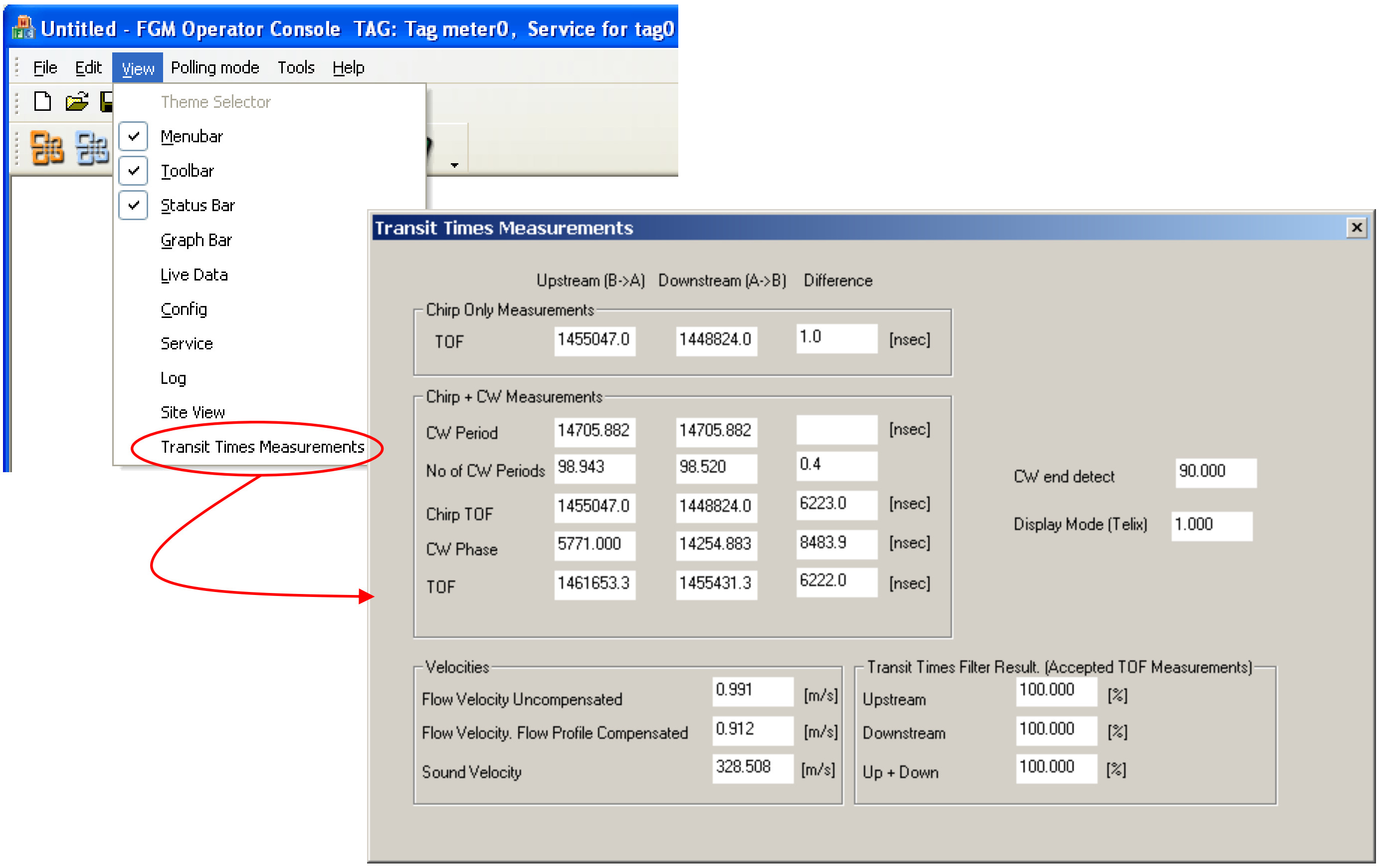


Figure 96 **The Transit Time Measurements window, with the Chirp and CW measurements, the uncompensated and flow profile compensated flow velocity and velocity of sound, and the % used transit time measurements.**

3.9 Help About Window

The **Help** → **About** window displays the program version of the Operator Console, ref. Figure 97.

Figure 97 The Help About window, with information on the O&SC software version.

7. MAINTENANCE INSTRUCTIONS

7.1 Maintenance Procedure

7.1 Maintenance Procedure

1. Purpose

The purpose of this procedure is to describe the necessary maintenance and preventive maintenance for the Fluenta Flare Gas Meter, FGM 160.

2. Abbreviations/Definitions

2.1 Abbreviations:

FGM	Flare Gas Meter
TFS	Transducer Full Size
O&SC	Operator & Service Console

2.2 Definitions:

N/A

3. General

The FGM 160 requires only minimum maintenance. It is a system with no mechanical moving parts. Maintenance is carried out if an error is detected or suspected to have occurred. In addition, Fluenta strongly recommends a periodical maintenance routine to secure the operational uptime of the meter. Below checks are standard procedure. Take contact with Fluenta Service&Support for more information or booking of maintenance.

The instructions are given for each major component in the flare gas metering system and the time periods between each activity is also specified.

4. Field Computer Unit

Every six months the following should be checked:

4.1 Connectors

Check that all connectors in the EEx-e housing are properly connected and that there is no corrosion or contamination on the terminals.

4.2 Field Computer Preventive Maintenance

Every twelve months the following should be carried out:

4.2.1 Inspection for Damages

Inspect the FGM 160 housing for damages. Make sure that the EEx-e housing draining is operating as intended and that there is no contamination on the inside.

4.2.2 Inspection of EEx-d Enclosure Sealing

The EEx-d enclosure shall be inspected at least once every 12 months, in order to ensure that the explosion proof sealing is not damaged. The inspection should be carried out under conditions that will **NOT** lead to any moisture inside the EEx-d enclosure. Carefully remove the sunshield and place it in a safe place to ensure no

damage while working with the EEx-d enclosure, ref. Figure 98. Thereafter remove the locking-screw at the side of the EEx-d enclosure, before loosening the EEx-d enclosure carefully by turning the enclosure counterclockwise. After inspection of the O-ring and the threads, put copper paste on the threads before carefully sliding the EEx-d enclosure back in position. By turning the EEx-d enclosure clockwise, fasten the enclosure until the mounting hole for the locking screw is aligned with the rear EEx-e cover. Mount the locking screw and the sunshield in order to complete the operation.

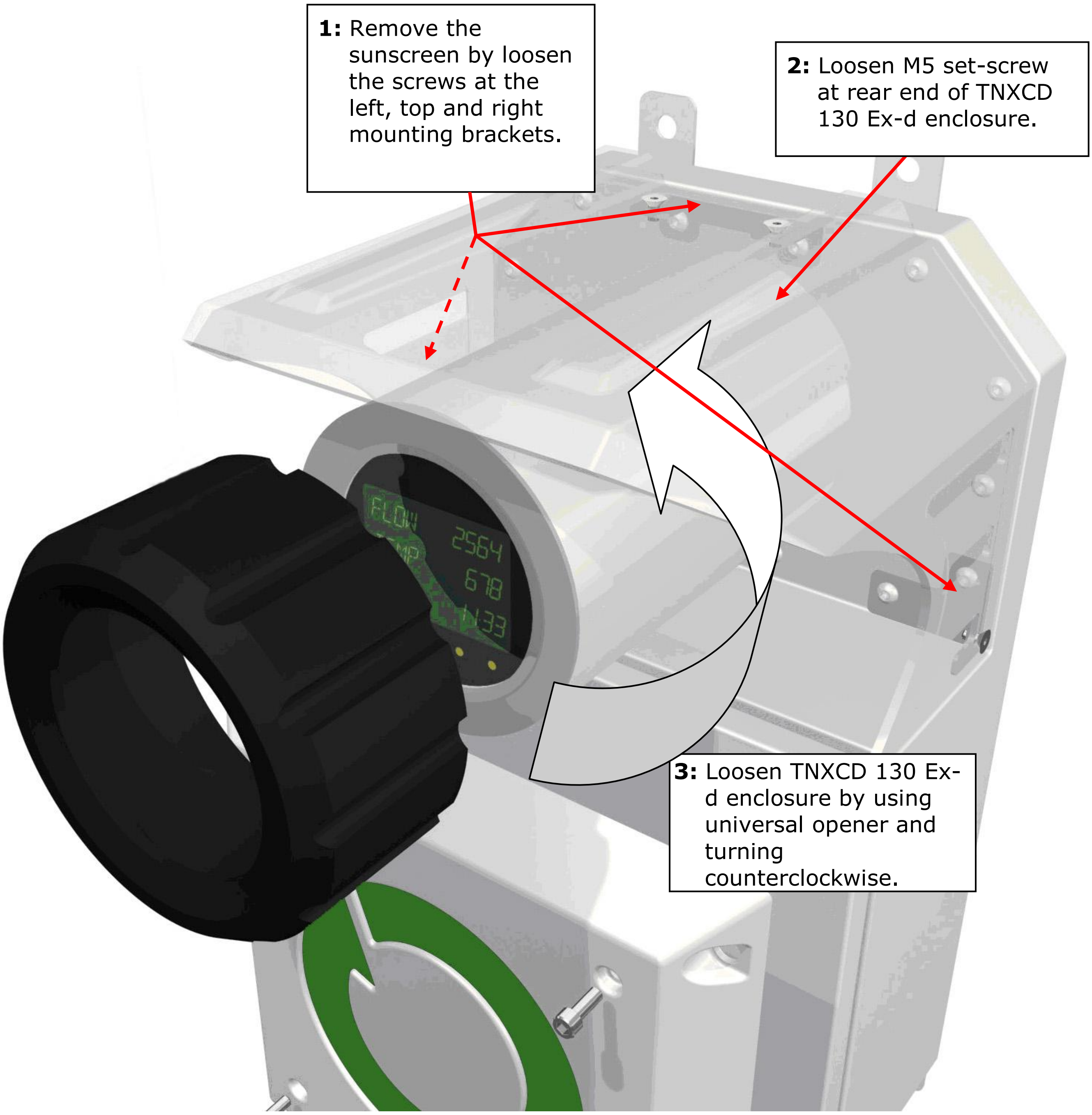


Figure 98 FGM 160 with description of how to dismount the TNXCD 130 Ex-d enclosure.

The EEx-d housing should under normal circumstances not be opened, but if required, the work should be performed in a work-shop in Safe Area or under good weather conditions.

If this operation must be carried out in field (hazardous area), a hot working permission must be issued prior to starting this work. Further, take notice of the warning on the Ex-d enclosure, regarding opening the Ex-d enclosure when explosive gas atmosphere is present, ref. Figure 99.

Considerations to weather and environments must then be taken. Never reassemble the EEx-d housing without replacing the gasket and the silica gel package.

Figure 99 FGM 160 WARNING label regarding opening the Ex-d enclosure when an explosive gas atmosphere is present.

4.3 Functional Check

Every twelve months or after shutdown the following should be carried out:

Check all meter functions and if any indications of malfunction, go through the Factory Acceptance Test Procedure for FGM 160, Fluenta doc. no. 62.120.003. This should preferably be carried out by Fluenta personnel, generally in collaboration with personnel responsible for daily operation of the system.

In addition to the procedure already mentioned above, a reliable zero point check and if required, adjustment for the different transmitted ultrasonic signals should be carried out. Fluenta service personnel are making use of a portable, special designed box for this purpose.

Different signals will also be analysed by Fluenta personnel, using the Operator & Service Console (O&SC) program. The O&SC displays important information of how the system operates, and how to troubleshoot potential errors, as the signals can be interpreted, compared and optimised if necessary.

Using experienced and qualified Fluenta personnel once a year to run a total system functionality check is recommended as this will decrease the possibility for a system malfunction and increase the system reliability.

4.4 Remote System Performance Diagnostics

By operating the O&SC remotely, remote system performance diagnostics can be carried out. This can either be carried out by the operator or by Fluenta through a remote support agreement.

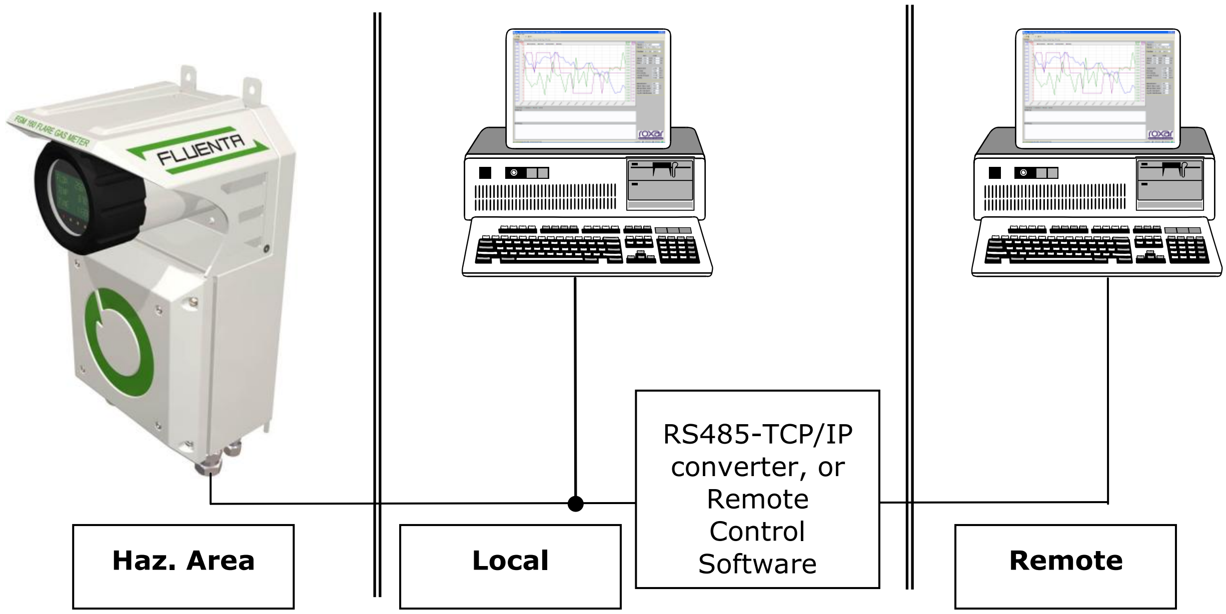


Figure 100 Local and remote control of the FGM 160 Field Computer by using the Operator & Service Console software.

5. Transducers and Ball Valves

5.1 Applicable for Transducer Full Size (TFS)

Every six months or after shutdown the following should be checked:

- Make sure that all nuts and bolts between the transducer holder and the ball valve and between the ball valve and the transducer unit are properly tightened.
- All flanges must be parallel.
- Check that the ball valves are open (not in contact with the transducers).
- Check that the nut (on fitting) at the end of the packing box is tight.

6. Cables

Inspect transducer cables and the FGM 160 cables for damages. Make sure that the cables do not have any sharp bends and ensure that there is no contact between the cables and sharp edges that can cause damages. Interfering equipment in the surroundings must be kept in a safe distance from the cables and the rest of the FGM 160 equipment.

7. Lubrication

Refer to 4.2.2 for parts that need lubrication as preventive maintenance.

8. References

N/A

8. SPARE PARTS LIST

8.1 SPIR

FGM 160 - SPARE PARTS LIST AND INTERCHANGEABILITY RECORD

FLUENTA

SPIR DOC. NUMBER	:	74.120.001/D
MESC GROUP	:	31
AUTHORISED FOR PURCHASE BY	:	32
REQUIRED ON SITE DATE	:	33

For explanation of columns see next sheet

MANUFACTURER'S / SUPPLIER'S SPARE PARTS DATA

1 EQUIPMENT REG. OR TAG NO. — 2 MANUFACTURER'S MODEL OR TYPE — 3 MANUFACTURER'S SERIAL NO. — 4 NO OF UNITS — 5 NUMBER OF PARTS PER UNIT

TOTAL NO OF IDENTICAL PARTS INSTALLED	ITEM NUMBER	DESCRIPTION OF PARTS	MATERIAL SPECIFICATION	FLUENTA DRAWING NO. INCL. POS. NO.	SUPPLIER OR REMARKS	PART NUMBER MANUFACTURER	PART NUMBER SUPPLIER	MESC NUMBER	UNIT OF MEASURE	SPARE PART PRICE (CURRENCY: see price lists Service⋑ DATE: see price lists Service&Sup)	DELIVERY TIME IN WEEKS	Spare Parts Recommended by Manufacturer: COMMISSIONING	INITIAL (1 to 2 years)	NORMAL OPERATION (5 to 10 years)	CRITICAL	Spare Parts Recommended by: COMMISSIONING	INITIAL	NORMAL OPERATION	CRITICAL	PHYSICAL STOCK	QUANTITY TO BE ORDERED
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	1	FGM 160 Ultrasonic Sensor Pair - TFS *) (STANDARD)	Titanium/SS 316	77.120.355	Fluenta	9600506	9600506				3	0	0	1	1						
0	2	FGM 160 Ultrasonic Sensor Pair - TFS *)	Titanium/6Mo	77.120.355	Fluenta	9600507	9600507				16	0	0	1	1						
0	3	FGM 160 Field Computer - PCB Stack LD	NA	NA	Fluenta	9600401	9600401				2	0	0	1	1						
0	4	O-ring for Ex-d enclosure; 120,33 x 2,62 mm	NBR 70	NA	Fluenta	9600403	9600403				2	2	2	2	2						
0	5	Fuse; 1,25 A, 250 VAC, Littelfuse 216 1.25P or 216 001.P	NA	NA	Fluenta	9600525	9600525				2	2	2	2	2						
0	6	FGM 160 Ex-d/e Field Computer Lid Cover	Coated ABS	30458_01_01_prt_d	Fluenta	9600351-2	9600351-2				2	0	0	1	1						
0	7	FGM 160 Ex-d/e Field Computer Sunscreen	Coated ABS	30458_01_02_prt_c	Fluenta	9600352-2	9600352-2				2	0	0	1	1						
0	8	Moxa 1250i	Nport 1250i	n/a	Fluenta	9600353	9600353				2	0	0	0	0						

6 MESC NO. EQUIPMENT ORDER REF. NO.

NOTES: 36

REMINDER:
MANUFACTURERS TO ATTACH TO THIS FORM ALL DRAWINGS AND PARTS LISTS

FOCAL POINT MANUFACTURER /SUPPLIER INCLUDING PHONE NUMBER 35

Contact person: Service Coordinator
Phone no.: +47 55 29 38 85
Fax no.: +47 55 13 21 60
E-mail: support@fluenta.com

7 CLASSIFICATION OF EQUIPMENT

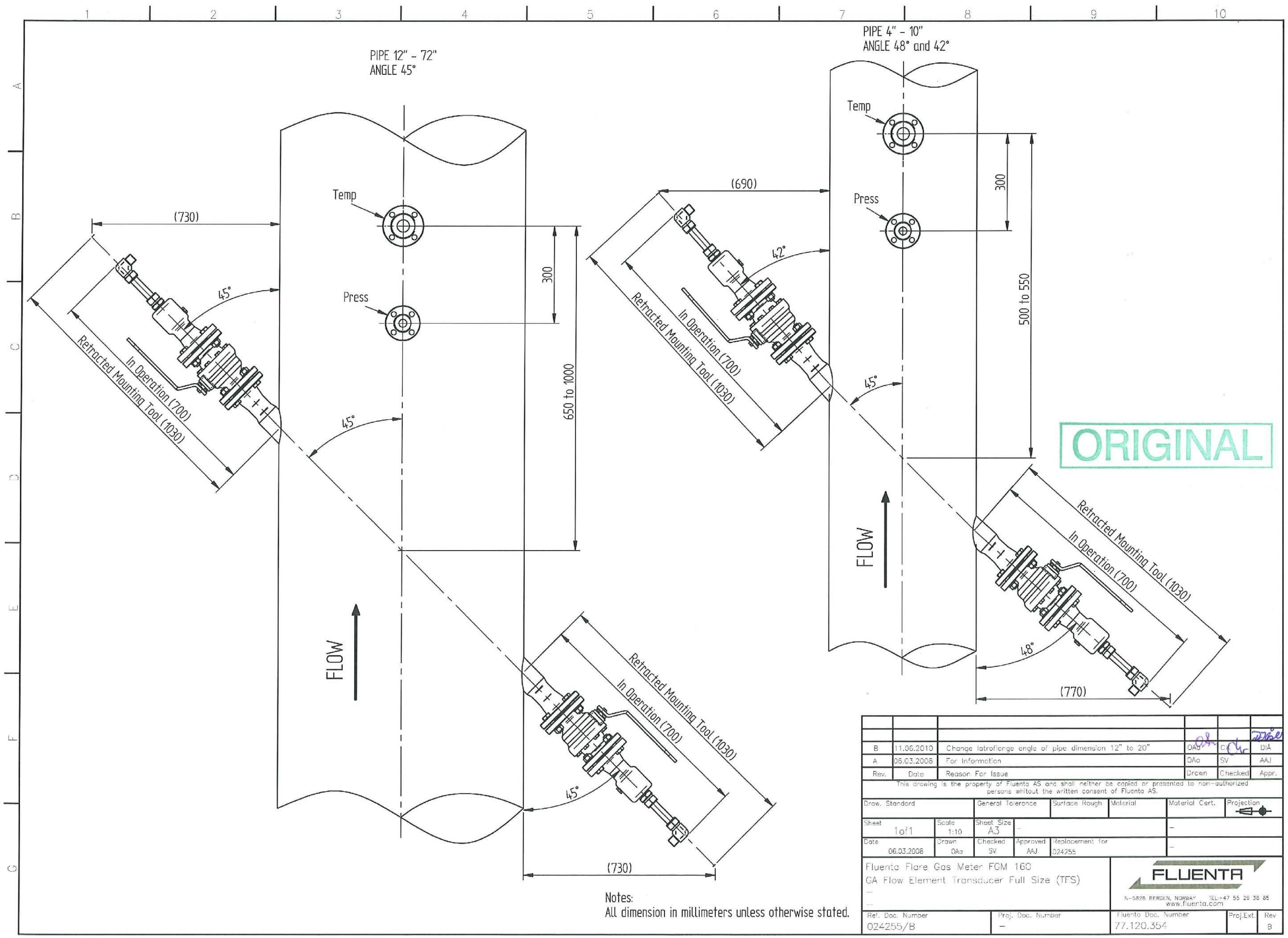
EQUIPMENT	FGM 160 Flare Gas Meter
MANUFACTURER	Fluenta AS
SUPPLIER	Fluenta AS, Tel. +47 55 29 38 85
PROJECT	
PLANT	
COMPANY	

STATUS OF SPIR				
REVISION	A	B	C	D
DATE	2007.12.12	2008.08.15	25.01.2011	23.03.2011
SIGNATURE	AAJ	AAJ	JJB	JJB
PAGE NO.	1	OF	1	
REQUISITION NO.				

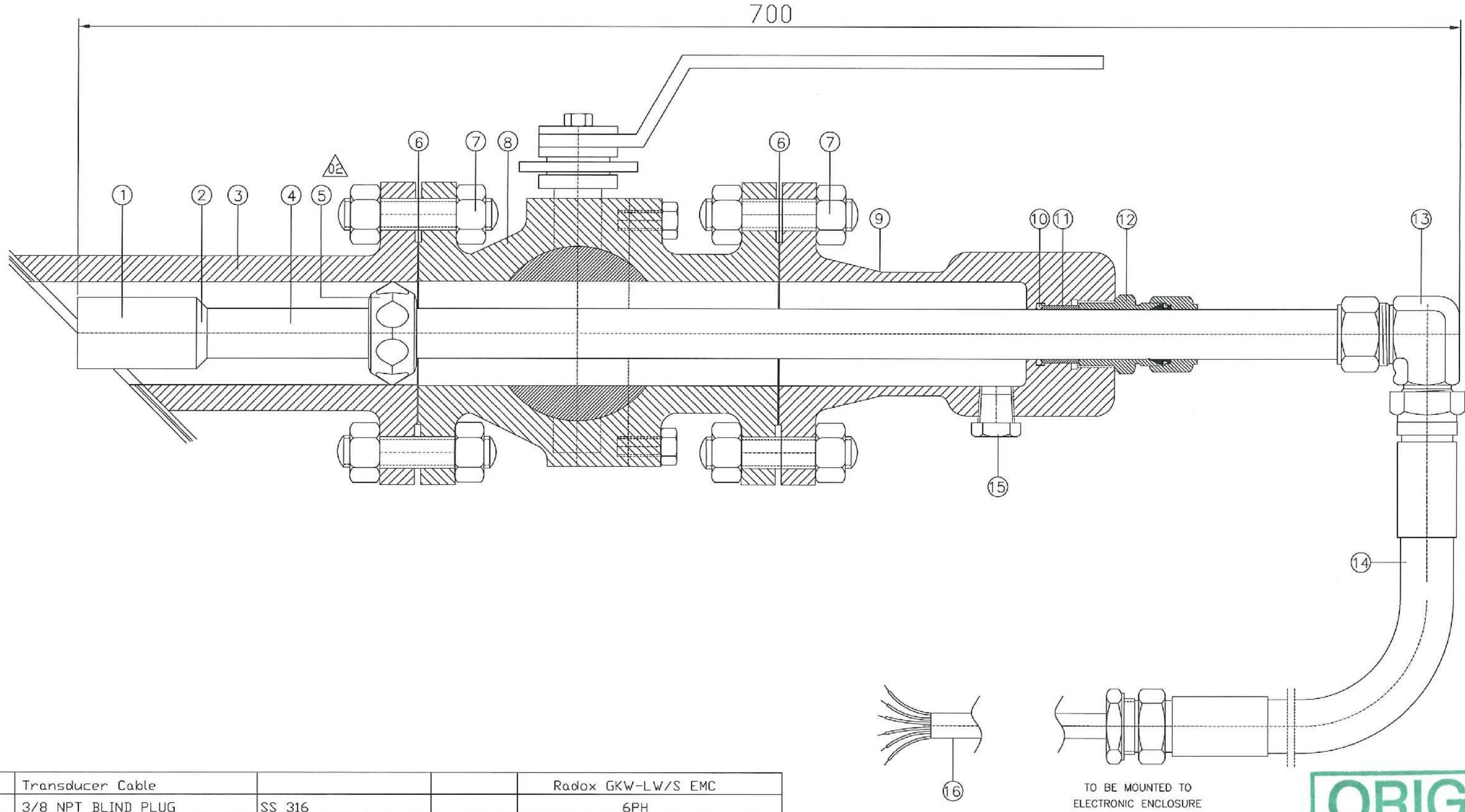
*): TFS - Transducer Full Size

9. DRAWINGS

9.1 General Arrangement Flow Element - TFS



9.2 General Arrangement Sensor Unit – TFS with Radox cable



ORIGINAL

Qt.	Item	Description	Material	Dwg.no.	Remarks
1	16	Transducer Cable			Radox GKW-LW/S EMC
1	15	3/8 NPT BLIND PLUG	SS 316		6PH
1	14	FLEXIBLE ARMOURED TUBE, 3m	NEOPR./NITRIL		Lengths up to 10m on request
1	13	TUBE FITTING - ELBOW	SS 316		M25MSEL3/4N
1	12	TUBE FITTING	SS 316		M25MTC1R
1	11	TEFLON RING	PTFE		
1	10	O-RING 24.99 x 3.53	VITON		BS 214
1	9	PACKING BOX	SS 316		Option: Acc. to project spec.
1	8	BALL VALVE 2" ANSI 150 # RF	WCC/LCC/SS316		Pekos
8	7	STUDBOLT w/2 NUTS 5/8"x85mm	A 193/B7 or A320/L7		
2	6	GASKET 2" 150 LBS	SS 316		Spiralwound Non-Asbestos
1	5	GUIDE RING	PTFE / SS316		Guide mater.: PTFE
1	4	EXTENTION ROD	SS 316		Option: Acc. to project spec.
1	3	TRANSDUCER HOLDER	See spec.		
1	2	ADAPTER FOR TRANSD.HEAD	TITANUM		
1	1	TRANSDUCER HEAD	TITANUM		

Rev.	Date	Reason For Issue	Drawn	Checked	Appr.
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
B	27.04.2009	Updated Information	OAa	SV	AAJ
A	06.03.2008	For Information	OAa	SV	AAJ

Draw. Standard	General Tolerance	Surface Rough	Material	Material Cert.	Projection
AutoCAD 2000LT	-	-	-	-	

Sheet	Scale	Sheet Size		
1/1	%	A3	–	–

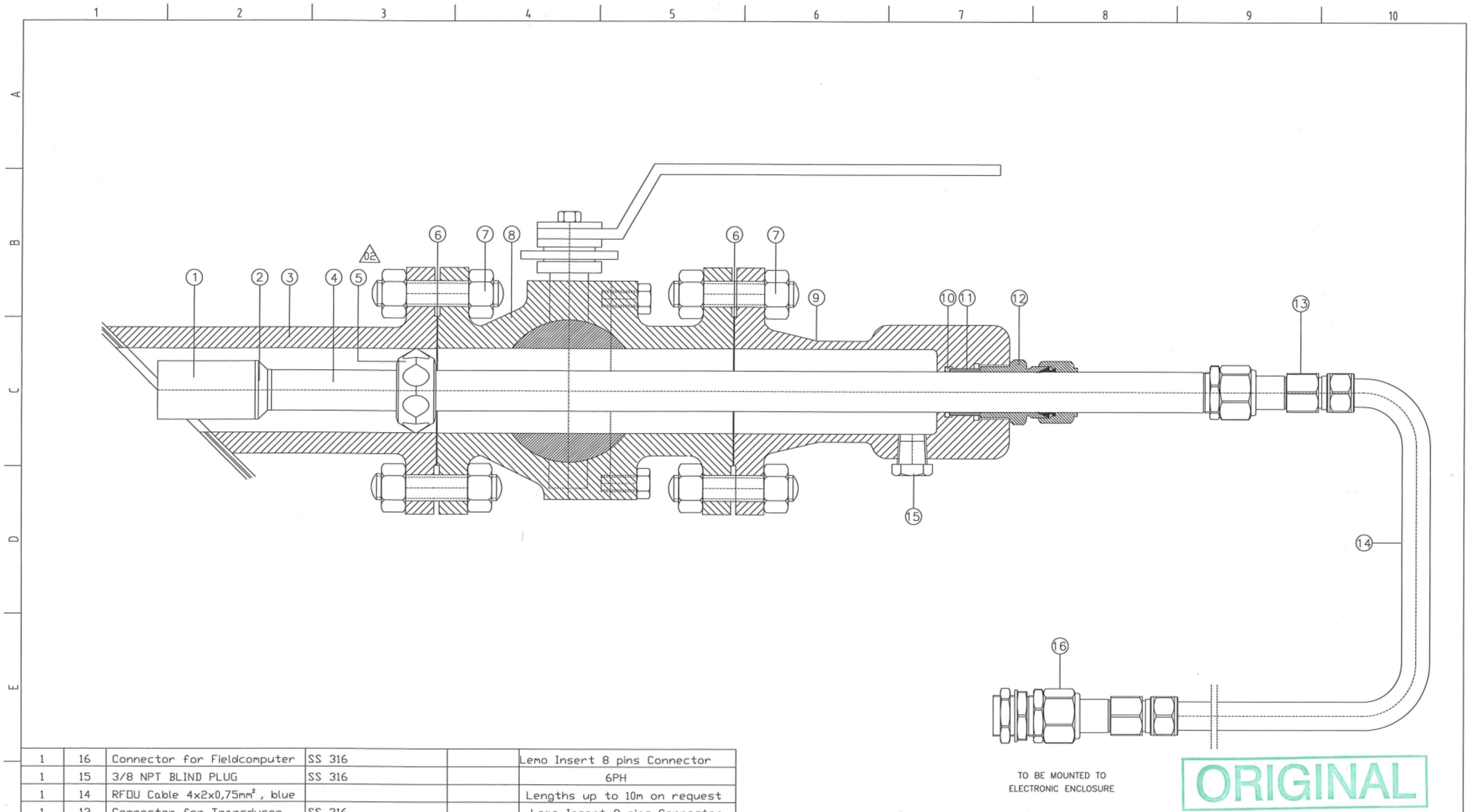
Date	Drawn	Checked	Approved	Replacement for	
06.03.2008	OAa	SV	AAJ	024257/A	–

Fluenta Flare Gas Meter FGM 160
GA Sensor Unit
Transducer Full Size (TFS)

FLUENTA
N-5828 BERGEN, NORWAY TEL:+47 55 29 38 85
www.fluenta.com

Ref. Doc. Number	Proj. Doc. Number	Fluenta Doc. Number	Proj.Ext.	Rev
024257/A		77.120.355		B

9.3 General Arrangement Sensor Unit – TFS with RFOU(c) cable



Qt.	Item	Description	Material	Dwg.no.	Remarks
1	16	Connector for Fieldcomputer	SS 316		Lemo Insert 8 pins Connector
1	15	3/8 NPT BLIND PLUG	SS 316		6PH
1	14	RFOU Cable 4x2x0,75mm², blue			Lengths up to 10m on request
1	13	Connector for Transducer	SS 316		Lemo Insert 8 pins Connector
1	12	TUBE FITTING	SS 316		M25MTC1R
1	11	TEFLON RING	PTFE		
1	10	O-RING 24.99 x 3.53	VITON		BS 214
1	9	PACKING BOX	SS 316		Option: Acc. to project spec.
1	8	BALL VALVE 2" ANSI 150 # RF	WCC/LCC/SS316		Pekos
8	7	STUDBOLT w/2 NUTS 5/8"x85mm	A 193/B7 or A320/L7		
2	6	GASKET 2" 150 LBS	SS 316		Spiralwound Non-Asbestos
1	5	GUIDE RING	PTFE / SS316		Guide mater.: PTFE
1	4	EXTENTION ROD	SS 316		Option: Acc. to project spec.
1	3	TRANSDUCER HOLDER	See spec.		
1	2	ADAPTER FOR TRANSD.HEAD	TITANUM		
1	1	TRANSDUCER HEAD	TITANUM		

Rev.	Date	Reason For Issue	Drawn	Checked	Appr.
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
A	02.09.2010	For Information	CKr	SV	GS

Draw. Standard	General Tolerance	Surface Rough	Material	Material Cert.	Projection
AutoCAD 2000LT	-	-	-	-	

Sheet	Scale	Sheet Size		
1 / 1	%	A3	–	–

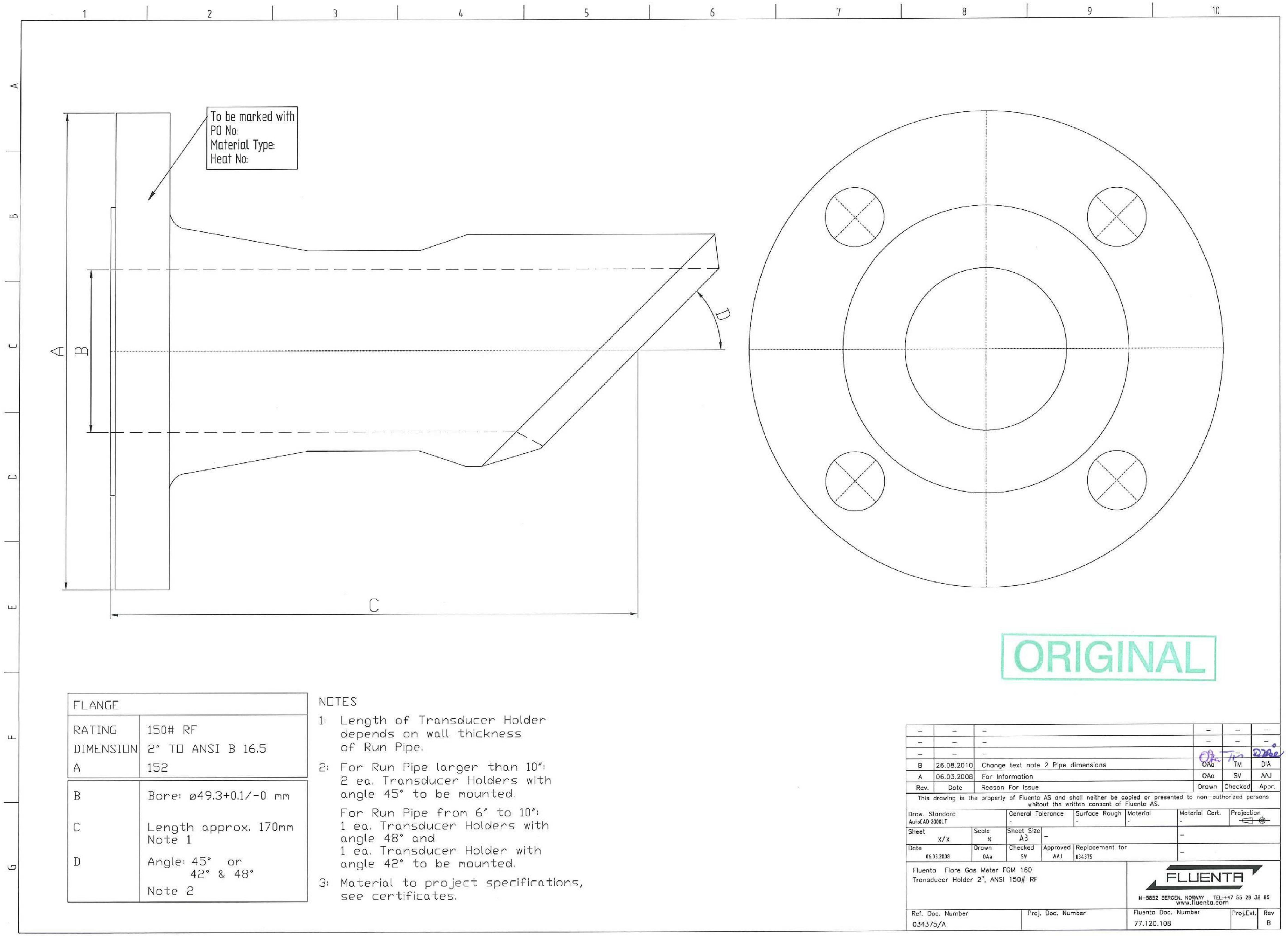
Date	Drawn	Checked	Approved	Replacement for	
02.09.2010	CKr	SV	GS	-	–

Fluenta FGM 160 Flare Gas Meter
GA Sensor Unit
Transducer Full Size (TFS) with Lemo Insert Cable Connector

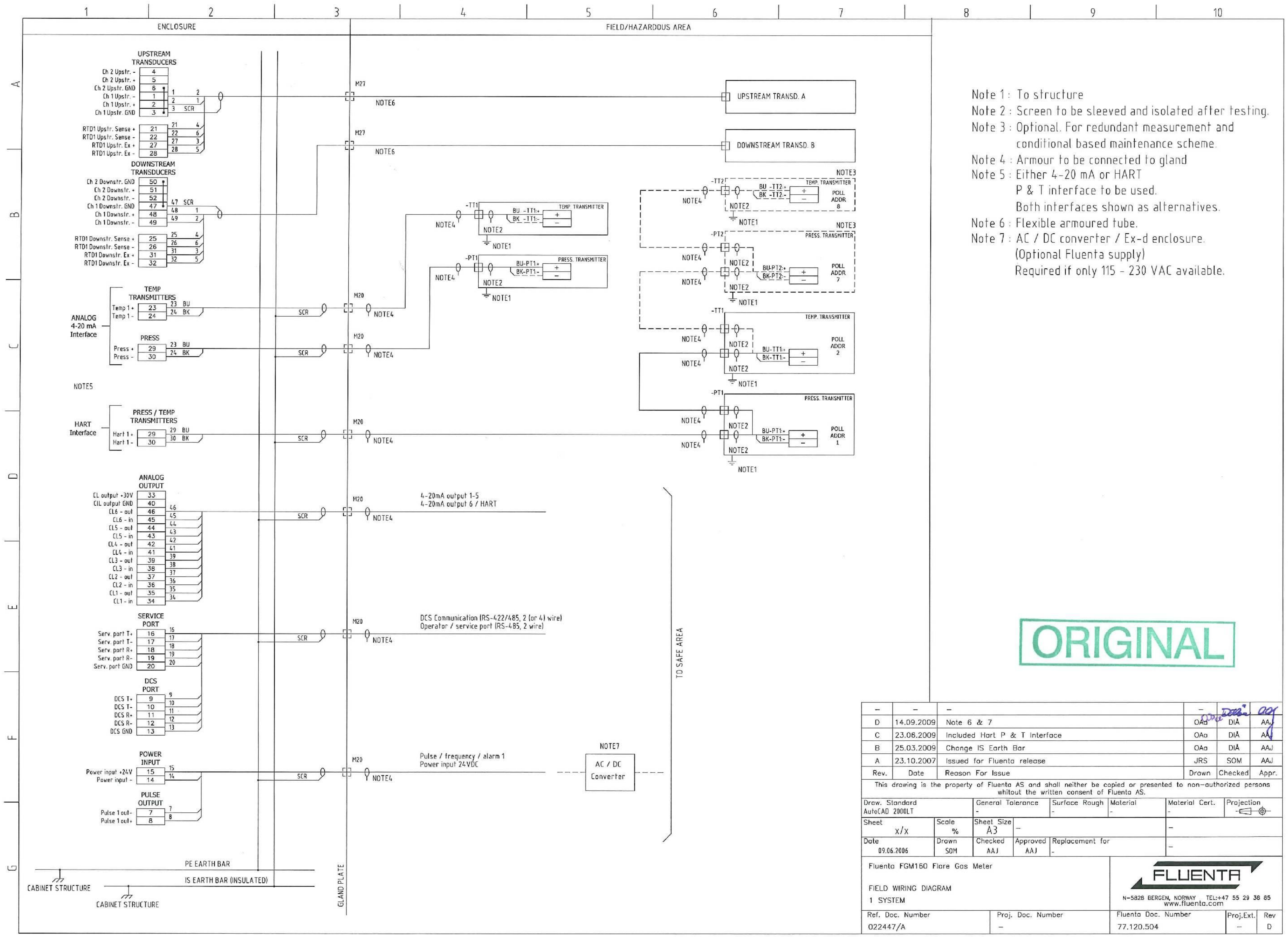
FLUENTA
N-5828 BERGEN, NORWAY TEL:+47 55 29 38 85
www.fluenta.com

Ref. Doc. Number	Proj. Doc. Number	Fluenta Doc. Number	Proj.Ext.	Rev
–		77.120.362		A

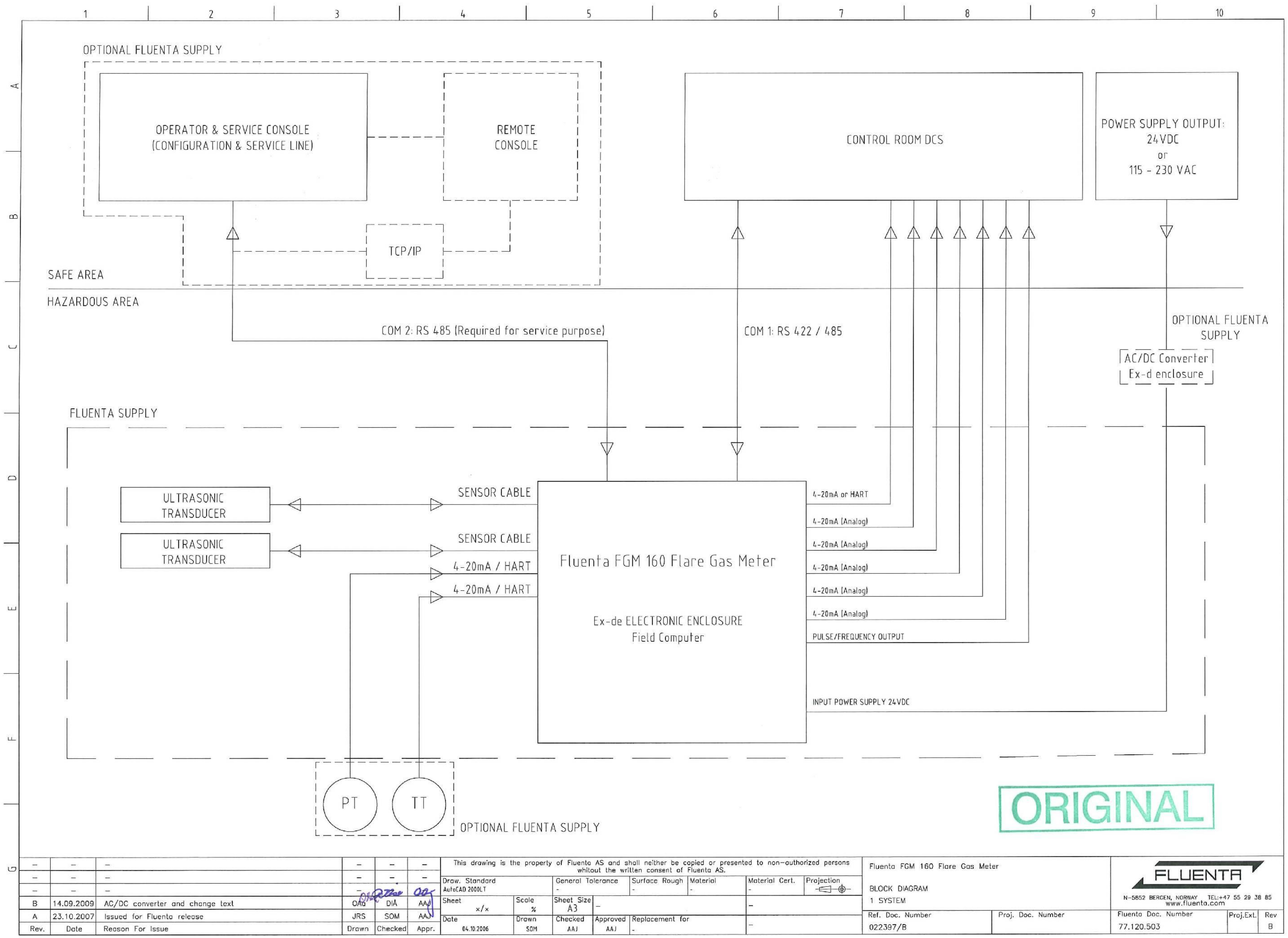
9.4 Transducer Holder, 2", ANSI 150# RF



9.5 Field Wiring Diagram, 1 System



9.6 Block Diagram, 1 System



9.7 General Arrangement Field Computer